The Blast Furnace and Steel Plant

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The Blast Furnace and Steel Plant

Vol. XIV PITTSBURGH, PA., JULY, 1926 No. 7

Refractories for Open-Hearth Furnaces

IT is reliably stated that the cost of repairing and rebuilding the basic open-hearth furnace is from 35 cents up to $2.50 per ton of steel produced. Most of the rebuilding expense is directly or indirectly due to the failure of the refractories used; and what is more, for many years material improvement in furnace design and efficiency has been prevented almost entirely by the limitations of the refractories available. Of course these facts are well known as many studies have been made and articles published thereon, but in the main they are generalizations based on experiences of steel-makers or specialists in refractories.

The study of open-hearth refractories is not a clean-cut problem; rather it is one affected by such conditions as operating temperatures, furnace design, and operation, and chemistry and equilibria in slags, metal and refractories. All of these affect the life of refractories. A complete investigation of this problem was projected by the U. S. Bureau of Mines at its Northwest Experiment Station at Seattle about three years ago and continued to a more or less definite conclusion at its Pittsburgh Experiment Station, in contact with its Ceramic Station at Columbus, Ohio, by the end of 1925. The last part of this work was done in connection with fellowships of Carnegie Institute of Technology and the Metallurgical Advisory Board which represents the iron and steel industry.

The result of this research, which covered extensive study of open-hearth shops in the Pittsburgh district and laboratory work, now appears as a 126-page printed report, Bulletin 23 of Carnegie Institute of Technolgy. An open-hearth specialist has described this as a splendid contribution to the literature and knowledge of the subject, and the report has a message of some definiteness. It is imperative that research in the development of new or improved refractory bodies and standard tests therefore should continue regardless of whether such new products prove to be of immediate practical value in present open hearths. Much of the possible improvement in furnace design depends upon development of better refractories; and conversely, new refractories and methods of construction will probably show their full value only when used in furnaces designed to give better efficiency in the use of heat and operating time.

General Principles of the Beneficiation of Iron Ores*

By T. T. READ†

PART III

THE amount of alumina present in iron ore is variable and depends on the origin of the ore. If the orebody is a residual product from the solution and removal of other constituents of the original deposit contained minerals which on decomposition tend to break down into clay-like substances, the alumina content of the ore may be high. This is especially true of the brown ores of the residual type and also of gossan deposits. On the other hand, in the Lake Superior district, the original material was low in alumina and consequently there are few mines where the alumina content of the ore will average over 3 per cent for a season's shipment. Sedimentary deposits, such as those of Newfoundland, and the Clinton ores, are more likely to range between 3 and 7 per cent alumina. Crude magnetite ores of igneous origin are likely to range between 5 and 10 per cent alumina, but by magnetic concentrating processes alumina is reduced to less than 1 per cent in the final product. The alumina content of the hematite ores of the Birmingham, Ala., district ranges from 2 to 5 per cent. It thus appears that 90 per cent of the ore sent to American furnaces will not average over 3 per cent Al_2O_3. As blast-furnace slag ranges between 30 to 40 per cent SiO_2 and 10 to 15 per cent Al_2O_3, (the average is 35 per cent SiO_2 and 13 per cent Al_2O_3) and, as pointed out in the preceding chapters, the average silica content of the ore mixture sent to American furnaces is somewhere near 8 per cent, it is seen that on the average the alumina content of iron ores does not constitute a problem, for on the average it is in about the proportion to yield slag of the desired composition with the SiO_2 present. Experiments made at Steelton, Pa., and cited by H. H. Campbell,‡ indicate that the Al_2O_3 content of the slag can be as high as 33 per cent and the furnace still work well.

All slags contain more or less magnesia and it has been argued that spinel, an infusible compound of the composition $Mg(AlO_2)_2$, is formed if alumina is high in a slag that also contains magnesia. The viscosity of iron blast-furnace slags of varying composition has been extensively investigated by A. L. Feild and P. H. Royster§ of the bureau of Mines, who conclude that the temperature-viscosity relations of an iron blast-furnace slag are, for practical purposes, entirely determined by the relative percentages of lime, alumina, and silica, provided that the magnesia does not exceed 7 or 8 per cent. As a rule magnesia is unimportant in iron ores, and when it is present in any notable amount in the blast-furnace charge it is usually in the limestone and, to a lesser degree, to the coke ash, which sometimes contains as much magnesia as it does lime. In the manufacture of basic pig iron under rigid specifications as to permissible sulphur and silicon content, dolomite is used as flux instead of limestone, in the belief that a slag high in MgO yields pig that is lower in sulphur.

There is also discussion as to whether, in the proportioning of a blast-furnace slag, the alumina should be regarded as a base or as an acid. Elbers says that if the silica is low the alumina acts as an acid; if the silica is high the alumina acts as a base. It is scarcely possible to consider the matter in so simple a light and Feild and Royster have more correctly designated it as a ternary system $CaO\text{-}Al_2O_3\text{-}SiO_2$. This is, however, a phase of furnace practice which need not concern us here, and has merely been referred to in order to make clear that from the chemical standpoint alumina in the iron ores now being utilized offers no special problem other than its effect of adding to the total non-ferrous material of the ore.

Another effect of alumnia in iron is that its presence usually adds to the moisture content of the ore. As already pointed out, alumina when present, is commonly in the form of clay or clay-like substances. Such substances generally contain a considerable percentage of colloids and, as pointed out in the preceding chapter, the colloids are able to adsorb water on their surfaces in very considerable amount. The alumina, therefore, not only decreases the iron content by its own presence, but also by indirectly increasing the amount of moisture present, and thus has a double effect in decreasing the iron content of the ore as mined.

When for these two reasons it becomes necessary or desirable to increase the iron content of the ore by beneficiation processes before sending it to the blast furnace, the removal of alumina by mechanical means ordinarily involves but little technical difficulty, the main factors being the cost of the operation and the loss of iron along with the non-ferrous constituents. For this purpose the log-washer may be said to be the standard device. This apparatus, which takes its name from the fact that the earliest ones were tree trunks with paddles driven into their sides, propels the ore up a slight incline against a current of water, thereby disintegrating lumps from which the water current carries away the fine material. For the removing of clayey material this is extremely effective, but in a beneficiation process it is usually desired to remove all the impurities that may be present in the ore. As already pointed out, silica is the principal offender and it is only in the special case where the silica exists in small free grains, as in the western Mesabi ores, already described, that a log-washer is very effective in decreasing the silica content of the ore. Lime and magnesia seldom exceed 1 per cent each in Lake Superior iron ores. Of the cargo analyses for 1924 from 70 different properties on the Mesabi Range, given in the Lake Superior Iron Ore Association's handbook of analyses, only three exceed

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*Published with approval of the Director, U. S. Bureau of Mines.

†Formerly Safety Service Director, U. S. Bureau of Mines, and Superintendent of North-Central Experiment Station, Minneapolis, Minn.; now Assistant Secretary, American Institute of Mining and Metallurgical Engineers.

‡Manufacture and properties of iron and steel, fourth edition, 1907.

§Slag viscosity tables for blast-furnace work. Tech. Paper. 187, Bureau of Mines, 1918, 38 pp.

0.40 per cent CaO and the highest is 0.85 CaO; only two analyses exceed 0.40 per cent MgO and the highest is 0.70 per cent. The highest range in lime and magnesia is found in the ores from the Menominee range, where some properties show average lime analyses between 3 and 4 per cent and magnesia in about the same range.

In the hard Clinton ore of the Birmingham district the magnesia seldom exceeds one-tenth of the lime present, with 3 per cent as an upper limit. In the soft Clinton ores the lime seldom exceeds 1 per cent. Analyses of the brown ores of Alabama generally are of washed ore and do not give either lime or magnesia. The alumina in these washed ores usually ranges between 2 and 5 per cent.

Conclusions as to Alumina, Lime, and Magnesia in Ores.

The general conclusion from the above is that lime never occurs in iron ores in amounts that are excessive from the standpoint of slag requirements. While it is a possibility that in the case of ores high in lime which would require shipping considerable distances to the blast furnace, the necessary lime for slag requirements might perhaps be obtained more cheaply near the furnace, no such case is known, and lime may, at the present time, be disregarded as an impurity in iron ore that might be made the object of beneficiation. For the reasons set forth above magnesia may similarly be disregarded.

Alumina, on the other hand, is more likely to be the object of beneficiation processes, especially in small-scale operations. The washing of ores to free them from clay is one of the oldest and simplest operations in the metallurgical art, and it does not appear necessary to discuss the matter further here.

Phosphorus in Iron Ore.

Effect of Phosphorus in Steel—If we were only concerned with the making of pig iron from iron ore, the presence of phosphorus would present little objection. Phosphorus forms with iron a eutectic consisting of plates of Fe_3P interstratified with a saturated solution of that phosphide in iron; it increases the fluidity of cast iron, and gives it a fine "skin" with the result that it fills an intricate mold perfectly, and faithfully reproduces the lines of ornamental work. I have elsewhere* described how the Chinese introduce it into cast iron in order to make very thin castings, such as tea-pots. But as Fe_3P is brittle it has a weakening effect on the casting, and in large castings the liquid phosphide has a tendency to liquate away from the parts which solidify first, leaving them spongy. It is only when the phosphorus exceeds 1 per cent that it is objectionable on this score, and the average of Lake Superior iron ore is only 0.10 per cent P, which would correspond to less than 0.25 per cent in the pig iron. The Lorraine ores of Europe contain 1.5 to 2 per cent P which, coupled with the low iron content (30 to 33 per cent), yields a pig iron objectionably high in phosphorus, but fortunately is high enough so it can be used for steel-making by the basic-Bessemer process. The Alabama ores on the average do not contain more phosphorus than would yield a 1 per cent phosphorus pig iron, so that were it not for its harmful effect in steel-making the phosphorus content of American iron ores would not be a problem.

Allowable Percentage of Phosphorus in Steel.

General practice is that phosphorus in steel must not exceed 0.10 per cent.† The reason for this is not that the phosphorus weakens the steel, though over 0.12 per cent P does weaken the steel, but that steels containing phosphorus are liable to be brittle under shock, even though they may be fairly ductile. When the Bessemer process first came into use in the United States the principal use of the steel made by it was for railroad rails which, of course, could not be brittle under shock. The allowable phosphorus content of railroad rails has been extensively studied and the phosphorus allowed is set at 0.10 per cent in American practice. As the Bessemer process cannot eliminate any phosphorus from the pig iron and the blast furnace cannot eliminate any phosphorus from the ore, it follows that the only way to make Bessemer steel rails under 0.10 per cent P is not to use any ore in the blast furnace that will result in the steel made from it having over 0.10 per cent P. Ores in which the amount of phosphorus present did not exceed 1/1000 of the iron were accordingly designated as Bessemer grade ores, and are now generally referred to as Bessemer ores. Under present practice 55 per cent iron (natural) and 0.45 per cent P is defined as the standard Bessemer ore; assuming that the natural ore contains 10 per cent H_2O, this would give a phosphorus to iron ratio of 1 to 1360, but would deviate from it in proportion as the H_2O deviates from 10 per cent. In reckoning the value of the ore 0.45 per cent P is taken as zero and for a phosphorus content less than 0.45 per cent a premium is paid and for a content above 0.45 per cent a penalty is exacted; in 1923 the penalty for 0.60 per cent was 17¼ cents per ton and the premium for 0.005 was 71 cents per ton. This is not quite logical, of course, because an ore analyzing 55 per cent Fe, 2 per cent H_2O, and 0.45 per cent P would have a phosphorus-iron ratio of 1 to 1250; while a 58 per cent Fe, 10 per cent H_2O, 0.47 P ore would have a phosphorus-iron ratio of 1 to 1370. The latter ore would be penalized 2½ cents per ton for phosphorus, although it is really better than Bessemer grade. The first one escapes a penalty, although its phosphorus is markedly higher than the standard iron-phosphorus ratio.

Premiums and Penalties for Phosphorus in Ore—The system of premiums and penalties for phosphorus is based on the fact that all the phosphorus which goes into the furnace with the charge comes out at the bottom in the metal. In the lower zones of the furnace there are involved about equal weights of iron, coke, and slag. The reducing effect of the first two is so strong that the phosphorus is reduced and dissolves in the iron, forming Fe_3P. As all the phosphorus thus appears in the iron, the only way to control the amount of phosphorus in the iron is to control the amount in the material charged—that is, by mixing low-phosphorus ore with that higher in phosphorus to keep the average down. A premium for low-phosphorus ore and a proper discount for high-phosphorus ore is the logical and effective method of impelling the miner to produce the grades needed for the blast-furnace man.

The term Bessemer ore may perhaps tend to give the erroneous impression that ore of this grade is needed only for steel to be made by the Bessemer process. This, of course, is not true, because the acid open hearth cannot eliminate phosphorus any more than the Bessemer can. It is a little more elastic in its requirements, however, because in the pig-and-ore process if the ore used is very low in phosphorus it will, through its diluting effect, permit the use of pig that is a little too high in phosphorus to make steel of the proper grade by the Bessemer process.

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*Read, T. T., Primitive iron smelting in China. Iron Age, vol. 198, 1921, p. 451.

†See The effect of phosphorus on the resistance of low-carbon steel to repeated alternating stresses, by F. F. McIntosh and W. L. Cockrell, Bulletin 25, Carnegie Institute of Technology, 1925, 31 pp.

Phosphorus in the Open-Hearth Furnace—In the basic open-hearth the silicon and carbon are removed by iron oxide, which is either added in the form of ore or is produced on the surfaces of the scrap addition while the latter is melting down. The oxygen thus carried into the bath is able to oxidize the phosphorus, just as it is in the acid open-hearth and Bessemer processes, but instead of the phosphoric acid thus produced being immediately reduced again by the metal, as it is in these two processes, the high lime of the slag permits the formation of calcium phosphate, which is able to resist the reducing action of the metal. The less silica the slag contains the more phosphorus it is able to contain. The amount thus removed also depends on the amount of phosphorus oxidized; it must be oxidized before the slag can carry it off.

There is no upper limit in phosphorus in pig iron for the basic open-hearth except the point at which the phosphorus is high enough (over 2 per cent) to permit the use of the basic Bessemer. Iron ores in America are not high enough in phosphorus to permit a plant manager to rely on a regular supply of metal high enough in phosphorus to operate the basic-Bessemer process, and it is practically non-existant in America. In round figures, 50 per cent of the pig iron made in this country is basic—that is, of a grade suitable for making into steel by the basic open-hearth process; 30 per cent or a little more is of Bessemer grade, 12 to 15 per cent is foundry, and about 3 per cent is malleable.

Phosphorus in Ore not an Impurity Demanding Much Consideration—It will be seen from the foregoing that if the ore of a deposit is not naturally of Bessemer grade and therefore cannot hope to compete for the higher price paid for some Bessemer ore, it does not matter what the phosphorus content is, because by one process or another, steel of sufficiently low phosphorus content can be made from it. No beneficiation process is ever applied to iron ore to reduce its phosphorus content, because there is no known method by which it could be done at a profit. The difference between the price for 1923 Mesabi Bessemer ore (55 per cent iron natural, 0.045 per cent phosphorus dry) and 55 per cent non-Bessemer ore was only 23 cents per ton, and of recent years there has been more ore of Bessemer grade available than has found a market; some, at least, of Bessemer grade ore has been sold at the basic grade price. For these reasons it may be considered that, from the practical standpoint, phosphorus is not an impurity that commonly needs much consideration in the beneficiation of ore, especially as the magnetic concentration processes for iron ore are usually quite effective in reducing its phosphorus content.

In conclusion, it is of interest to note that the coke available for smelting iron ore in India contains enough phosphorus so it is impossible to make pig iron below 0.35 per cent P even from phosphorus-free ores.

Sulphur in Iron Ore.

Effect of Sulphur and Manganese in Iron and Steel—Sulphur resembles phosphorus in that it exhibits a tendency to accompany the metal through the iron and steel-making processes and appear in the final product. Like phosphorus it forms a brittle compound with the iron, which tends to make the whole mass brittle, especially at the rolling temperatures, because it is then liquid, and is like a liquid cement between the crystals of steel. Fortunately, if there is an excess of manganese in the steel over the amount required to combine with the sulphur present the sulphur unites with it in preference to the iron. Manganese sulphide is less weakening to the steel than iron sulphide, because it collects together in drops instead of spreading out in webs or sheets, as the iron sulphide does. The effect of manganese on sulphur in steel is discussed in more detail in the next chapter.

Elimination of Sulphur in the Blast Furnace—Sulphur differs from phosphorus in that it can in large part be eliminated in the blast furnace with a sufficiently high lime-magnesia ratio in the slag and a sufficiently high temperature in the furnace. The sulphur present in the charge will tend to be carried away in the slag as CaS. Not all goes off in this way, however, for most furnaces make about as much metal as they do slag, consequently there is opportunity for the sulphur to get into the metal. The exact relation of the various factors which affect the elimination of sulphur in the blast furnace has been discussed by H. M. Howe* who gives a table showing the individual and net effect of all the variables. It is enough for our purpose here to make the looser statement that if the blast furnace runs hot and the lime-magnesia ratio is high enough, a large part of the sulphur will go off in the slag as CaS, but unless the operator is careful enough it may remain with the iron to give trouble. Sulphur in rivet steel should not exceed 0.05 per cent and in malleable cast iron 0. 06 per cent for castings that require strength. In cast iron it should not exceed 0.085 per cent for soft and medium castings and 0.095 for hard castings.

Elimination of Sulphur in the Open Hearth—Some sulphur is eliminated in the basic open-hearth process, both because of the high CaO content of the slag, and also by the use of manganese as described in more detail in the next chapter. Elimination of sulphur is aided by thinning out the slag by the addition of fluospar just before the end of the operation. However, it is universally agreed that the best way to insure that the final steel will be low in sulphur is to keep low the sulphur content of the original materials charged into the blast furnace. Phosphorus ordinarily only gets into the blast furnace in the iron-bearing material, but unfortunately the larger part of the total sulphur is in the coke. The forms of sulphur in coke and their relation to blast-furnace reactions has been extensively studied by A. R. Powell formerly with the Bureau of Mines and the results of his study have been published.† As a rule, the relative amount of sulphur contributed by the ore is not high enough to warrant taking any steps for its reduction except in the two cases described below.

Examples of Treatment of Sulphur-Bearing Iron Ore—The iron-ore deposit at Cornwall, Pa., now owned and operated by the Bethlehem Mines Corporation is a soft magnetite, associated with green, pyritous shales, Siluro-Cambrian limestone and Triassic sandstone. It was first worked in 1740 and hence is the oldest iron mine now working in the United States. The ore was first mined from large pure masses, and the material which was interlaminated with the shales was saved for later magnetic concentration. The presence of the pyrite made it necessary to roast the ore before smelting in the blast furnace, as it contained up to 4 per cent sulphur. The practice of 40 years ago is described by S. G. Valentine* in the two papers cited below. He refers to Gjers kilns as being used, refers also to Westman kilns as in use in this country, and describes the results being obtained with the Davis-Colby kiln. Valentine states that at that time about 1,500,000 tons of pyritous iron ore was being roasted in the United States prior to smelting in the blast furnace, or twice what was being produced at Cornwall, so that it must have been in use at a number of places. Katahdin, Me., referred to as one of them, is not even mentioned in more recent lists of iron-ore localities.

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*Iron, steel, and other alloys, second edition, 1906, p. 397.

†Forms of sulphur in coke and their relations to blast-furnace reactions. Transactions American Institute Mining and Metallurgical Engineers, vol. 69, 1923, pp. 587-599; discussion, pp. 599-605.

At the present time the ore at Cornwall is being concentrated magnetically and the concentrate is sintered on machines which accomplish the roasting and sintering at the same time. This is the only instance in the United States known at present to the writer where iron ore is now being roasted to reduce its sulphur content, and while of much interest, the operation is so unusual as not to require consideration at any great length.

In the making of sulphuric acid by the burning of pyrite, high-grade sulphide is used (containing when pure 46.7 per cent iron) because low-grade material cannot be roasted down to as low a sulphur content as the purer material can. With pure ores, proper equipment and skillful operations the sulphur content can be reduced to 0.5 per cent; in practice it is usually about 2 per cent. When the sulphur is roasted off the residue, or pyrite cinder, is essentially iron oxide. Much of the imported Spanish pyrite and also much of the domestic ore from the Southern States contains enough copper so that it is worth while to recover it. The process generally used is the Henderson salt-leaching process, which is described in some detail by A. E. Wells and D. E. Fogg.†

The leached material is either nodulized or sintered and sold to iron blast furnaces. For nodulizing an ordinary cement kiln is used, 7 to 9 ft. in diameter and 100 to 125 ft. long, which is fired with powdered coal, generally 14 to 15 per cent of the weight of nodulized material being required. A special gas coal is used for this purpose. A 9-ft. kiln will produce about 200 tons of nodulized material per day. In some cases the product of the kiln is shipped just as it comes out; in other cases it is screened and the fine material returned to the head of the kiln, according to whether the buyer objects to fines or not.

The sintering of leached pyrite cinder is done on machines or grates such as are used for the sintering of magnetic concentrate, and the procedure is essentially the same. The fuel consumption is usually 7 to 10 per cent of the weight of the calcine, plus ½ to 1 gal. of fuel oil per ton, or its equivalent, to ignite the charge. As domestic pyrite production plus imports into the United States amounts to between 600,000 and 1,000,000 tons per year this is not an unimportant addition to the iron ore supply. No statistics are available to indicate the amount of cinder that is used for iron-making.

As a rule it is not necessary to employ any method for reducing the sulphur content of iron ore, but in cases where it became necessary the practice described above would indicate the line of attack.

(To be continued)

"Super-Materials" for "Super-Needs"

Philosophers tell us that the man satisfied with himself is going backward, and that a certain amount of "divine discontent" is required for progress. The same thing holds in engineering. Discontent with existing materials has always been the fore-runner of improved materials to meet those needs.

The definite statement of a problem is the most important step in its solution.

At the October meeting of the American Electrochemical Society, an opportunity will be given for the statement of such problems, at the Symposium on "Materials for Use Under Extreme Conditions."

A condition is not extreme if we can meet it readily. In the days of iron rails, present day conditions of service on jerkwater lines would have been extreme. But no matter how closely the improved materials may fit more exacting requirements, there are always some things the engineer would like to do could he find materials that would stand up under conditions he would like to impose.

Without going to absurdities such as a demand for a combination of properties wholly impossible of attainment as far as present knowledge can predict, there are many cases where the properties needed are only just around the corner from those now attainable.

Electrochemistry has provided the materials for use under many previously "extreme" conditions. It provides tungsten, chromium and vanadium for high speed steel, chromium for "stainless" steel, high-conductivity copper that fire-refining could not provide, refractories for the high temperature needs that electric smelting itself brought forth, abrasives fit for more exacting uses than natural abrasives, and so on through a long list.

It is logical therefore that the electrochemist, as a step toward filling more of these needs for "super materials" should seek to have stated what the "super needs" of today are.

At the symposium, papers will be presented on materials suitable for resisting extreme conditions and on extreme conditions not yet filled in the fields of corrosion, high temperatures, refractories, electrical insulation, chemical manufacture, etc. It is desired to supplement these papers by a compilation of a list of needs for superior materials, very briefly stated, and of super materials already satisfactorily developed for exacting needs. On the latter phase, indefinite statements or claims of an advertising nature are not desired and will not be admitted.

Suggestions for items either "super materials" or "super needs" to be included in this compilation and thus brought up for discussion will be gladly received by H. W. Gillett, Bureau of Standards, Chairman of the Symposium.

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*The desulphurization of pyritous iron ores. Transactions American Institute Mining Engineers, vol. 18, 1889, p. 78.

The Davis-Colby ore roaster. Transactions American Institute Mining Engineers, vol. 18, 1889, p. 303.

†Manufacture of sulphuric acid in the United States. Bulletin 184, Bureau of Mines, 1920, pp. 193-204.

Brushes for Direct Current Machines

Brushes Are Not, as Often Considered, Just Brushes and May Influence the Performance of a D. C. Motor According to Their Composition and Characteristics

By EARL B. STAVELY*

TO many men responsible for the operation and maintenance of electrical machinery, a brush is simply a piece of carbon. If a brush on a certain machine must be replaced they assume that any spare brush will be satisfactory, or if no spare brush is available they make one by cutting up any piece of carbon which may be at hand.

Satisfactory operation of d.c. motors and generators, regardless of the class of service, can be obtained only by giving careful attention to the selection and maintenance of the brushes. Many commutation troubles which lead to severe sparking are due to the use of the wrong type or grade of brush. An improper application of brushes also increases the cost of machine maintenance since it usually makes it necessary to replace brushes and resurface commutators at frequent intervals.

For these reasons it is important that, for each machine, brushes should be selected which are suitable for use with that machine and for the conditions under which it is operated.

Brush manufacturers offer scores of different types and grades of brushes, each of which is designed to meet the requirements of certain definite conditions of service. If the properties of these different brushes are carefully considered little difficulty should be encountered in obtaining a satisfactory brush for a given application. In some cases a satisfactory brush can be found only by trial of several grades. This is especially true when loading conditions are very severe or when difficult commutation problems are encountered. The grades which may well be tried under such conditions can be determined by analyzing the conditions of operation and by considering the properties of each type and grade of brush available.

An intelligent selection of brushes cannot be made unless one possesses some knowledge of the properties of brushes in general and of the properties required to meet the demands of different applications. A portion of this article will be devoted, therefore, to a discussion of these topics.

Properties of Brushes.

The properties of brushes which are of most importance in the majority of applications are: Current Carrying Capacity; Contact Resistance; Abrasive Qualities.

Other properties which must be given consideration under certain conditions include: Hardness; Density; Coefficient of Friction; Lubricating Qualities.

Brushes of different types and grades vary considerably in so far as these properties are concerned. If a brush is to be suitable for application in a given service it must possess the proper combination of these properties. Each of these will be discussed briefly in the following paragraphs.

Current Carrying Capacity.

The term Current Carrying Capacity means the current density at the contact between brush and commutator which should not be exceeded if serious overheating of the brush and commutator is to be avoided. Such overheating usually leads to severe burning and pitting of the brush face. This in turn causes sparking and the rapid wearing and burning of the brush.

Current carrying capacity is expressed in terms of amperes per square inch of brush contact with the commutator. One grade of brush may have a current carrying capacity of 60 amperes per square inch while the capacity of a slightly different grade may be only 30. Serious overheating of the brushes will occur if this latter grade is applied, for example, in a machine with a contact density of 50 amperes per square inch.

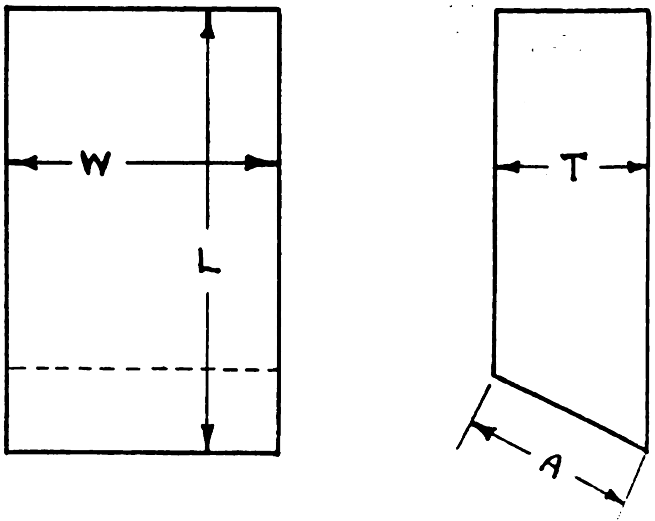

FIG. 1—Method of specifying brush dimensions. A—Arc of contact. L—Length. T—Thickness. W—Width.

The current density at the brush contacts can be estimated approximately for any given machine by dividing the current per brush stud by the brush contact area per stud.

The current per stud is calculated thus:

$$\text{Current per stud} = \frac{\text{Line Current}}{\frac{1}{2} \times \text{Number of Studs}}$$

This result is only approximate since it is based upon the assumption that there is an equal distribution of current between all studs of the same polarity, and since the shunt field current is neglected in the calculation. Allowance is not made in the calculation for the effects of local currents in the armature coils short circuited by the brushes. The result thus obtained will be sufficiently accurate, however, providing that a reasonable factor of safety is used when selecting from brushes of different allowable contact densities.

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The contact area per stud is calculated thus: Contact area per stud = (Number of brushes per stud × A × W) where A and W are the dimensions, in inches, of the contact of each individual brush as indicated in Fig. 1. Note that the distance across the brush face between tips is used in this calculation—not the thickness of the brush.

The current density is then:

$$\text{Current Density at Contact} = \frac{\text{Current per Stud}}{\text{Contact Area per Stud}}$$

Commutation troubles and brush and commutator deterioration occur most frequently at the higher loads hence in calculating contact densities for the purpose of brush selection the current at the maximum sustained load should be used.

Contact Resistance.

The term Contact Resistance means the electrical resistance of the contact between a brush and the commutator. This resistance varies with the current density at the contact, decreasing as the current density increases, and then increasing rapidly after the density becomes so high that the brush starts to glow due to overheating. The contact resistance of different types and grades of brushes vary over a rather wide range for the same contact density.

A low contact resistance is desirable since it reduces the voltage drop and energy loss at the brushes, factors which affect the efficiency and temperature rise of the machine. A high contact resistance is desirable in order to improve commutation, since a high contact resistance reduces the local currents in the armature coils short circuited by the brushes. As a compromise, therefore, a brush with a medium high contact resistance is often most satisfactory. In some cases a very high contact resistance is required in order to prevent commutation troubles and a suitable brush must be selected even though its use may have a marked effect upon the loss and temperature rise at the commutator.

Abrasiveness.

The abrasive qualities of a brush are determined by the amount of mechanical grinding action of the brush on the commutator. The abrasiveness of a brush depends upon the materials of which the brush is made and not simply upon its hardness. Some grades of very hard brushes are only slightly abrasive, while some grades of very soft brushes are quite abrasive.

The abrasiveness of any brush varies considerably with different conditions of application. Excessive overheating of a brush usually increases its abrasive qualities, especially during the period while the brush is hot. A deposit of copper on the brush face, resulting from poor commutation or other cause, will increase the abrasiveness of a brush.

The grinding action of a brush on a commutator also varies with the condition of the commutator face and brush face, with the brush pressure, and with the peripheral velocity of the commutator.

At first thought it might be assumed that the most desirable grade of brush would be one having very little abrasive action on the commutator. In certain cases, however, a highly abrasive brush is required to avoid brush and commutator troubles.

The properties required for different brush applications will be discussed later in this article.

Composition of Brushes.

The properties of a given grade of brush are determined by the materials of which it is made and by the methods used in its manufacture.

The materials used in brush manufacture include carbon, graphite, certain metals, and various kinds of abrasive material. These materials are properly mixed with a suitable binder and moulded under high pressure into blocks. These blocks are then baked at a high temperature, after which they are finished to the desired shape and dimensions.

Pure carbon brushes are very hard and have a low current carrying capacity. They are not widely used at the present time.

A widely used type of brush is made of carbon but the carbon is changed to artificial graphite during the process of manufacture. These brushes are called "graphitized-carbon" brushes. One method of manufacture involves the heating of the material to a high temperature by electric current, and the brushes thus made are called Electro-Graphitic brushes. They have a rather high current carrying capacity when compared with brushes of untreated carbon.

Brushes made of pure graphite are quite soft, have a high current carrying capacity, and have excellent lubricating qualities.

Certain grades of brushes are made of a mixture of carbon and graphite. The addition of the graphite increases the current carrying capacity and improves the lubricating qualities. The properties of brushes of this type can be varied over a wide range by varying the relative amounts of carbon and graphite used in their manufacture, hence brushes of this type are available in a variety of grades, each of which is suitable for definite conditions of application.

Metallized-Graphite brushes are made of a mixture of graphite and certain metals, the amount of metal used varying with the purpose for which the brush is intended. Brushes of this type are used only in special applications where the required current carrying capacity is so high that other types of brushes cannot be used. The purpose of the metal is to increase the current carrying capacity to the necessary value.

The general properties of the different types of brushes are compared in Table I, the comparison being made with those of the electro-graphitic brush since this type is most widely used.

TABLE I

PROPERTIES OF DIFFERENT TYPES OF BRUSHES

Type	Current Carrying Capacity	Contact Resistance	Hardness	Coefficient of Friction
Carbon	Low	High	Very Hard	Medium
Graphitized Carbon	Medium	Medium	Hard	Medium
Carbon-graphite	Med. High	Low	Med. Hard	Med. High
Graphite	High	Low	Soft	High
Metal-graphite.	Very High	Very Low	Hard	High

The Abrasive Qualities of each type vary over a wide range, depending upon the amount of abrasive material included in the materials of which the brush is made.

Brush Properties Required.

As noted previously, the conditions under which brushes are applied determine the type and grade of brush required. The brush properties required under certain conditions will be noted briefly here.

Brushes having some abrasive action on the commutator are required in case the mica is flush with the commutator. This is necessary in order that the brush can wear down the mica as rapidly as the copper bars are burned away by the current flow between brushes and commutator. High mica, and serious sparking, will result if non-abrasive brushes are used on machines in which the mica is not undercut. The degree of abrasiveness required depends chiefly upon the hardness of the mica and the natural tendency of the machine toward sparking.

Machines with slotted, or undercut, commutators should be equipped with brushes of very slight abrasive qualities. The only abrasive action required in this case is to keep the commutator face polished and clean.

Machines with slotted commutators should be provided with brushes of medium abrasiveness, however, in case severe overloads must be carried or in case commutation conditions are not good. This is necessary in order that the brushes will be able to wear away the burned surface of the commutator resulting from the heating and sparking which occurs under the conditions mentioned.

A brush of low contact resistance should be used in machine which show no tendency toward sparking, even under overload. The loss and heating at the commutator can be reduced by the use of such brushes under these conditions.

In case sparking occurs, however, due to local circulating currents in the armature coils short circuited by the brushes, it will be necessary to use brushes of rather high contact resistance if excessive sparking is to be avoided. Sparking due to this cause can often be greatly reduced by replacing the present brushes with a grade having a higher contact resistance.

The current carrying capacity of the brush must also receive careful attention. The contact density, calculated as explained previously, should be checked against the rated current carrying capacity of the brushes. Brushes of a higher carrying capacity should be used to replace existing brushes in case overheating of the brushes is found and commutation conditions indicate the presence of considerable local current in the coils short circuited by the brushes.

Other necessary properties will be noted in the following discussion of the selection of brushes for specific applications.

Stationary Motors.

Commutation conditions usually are quite better in these stationary motors. For these reasons a brush will usually prove satisfactory on motors with slotted commutators in this class of service if it possesses slight abrasive qualities. The coefficient of friction should be low if the commutator runs at a rather high peripheral velocity.

If the motors in this service have commutators with flush mica the brushes should be more abrasive and should have a higher contact resistance than those which are found satisfactory in motors with slotted commutators.

Both carbon-graphite and graphitized carbon brushes are widely used in these applications of electric motors. Artificially lubricated brushes are frequently found desirable in case poor commutating conditions are encountered.

Generators and Rotary Converters.

Power house generators and rotary converters are subjected to severe overloads which, while of short duration, occur at very frequent intervals. Rather severe sparking usually occurs during these periods of overload.

Brushes of rather high current carrying capacity should be used on these machines if serious brush burning is to be avoided during overload. A brush of medium abrasive qualities will keep the commutator face in good condition providing the commutator is slotted. A rather high abrasive brush will be required, however, if the mica is flush with the bars. Artificially lubricated brushes may well be used in this service in case commutation conditions are not good.

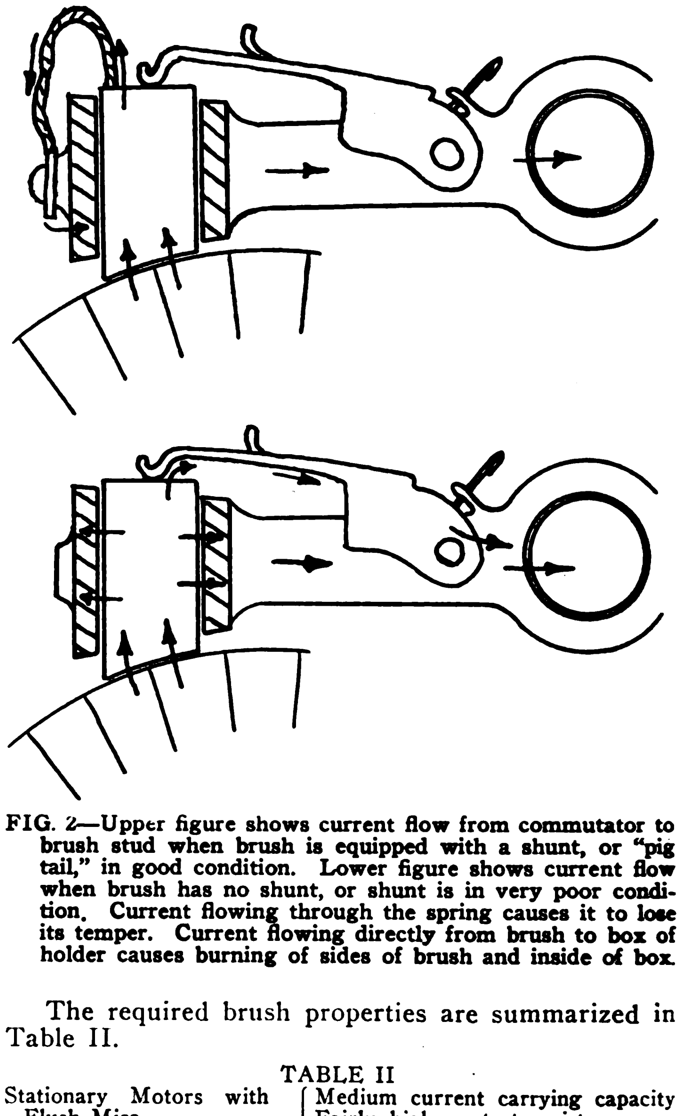

FIG. 2—Upper figure shows current flow from commutator to brush stud when brush is equipped with a shunt, or "pig tail," in good condition. Lower figure shows current flow when brush has no shunt, or shunt is in very poor condition. Current flowing through the spring causes it to lose its temper. Current flowing directly from brush to box of holder causes burning of sides of brush and inside of box.

The required brush properties are summarized in Table II.

TABLE II

Stationary Motors with Flush Mica..............	Medium current carrying capacity Fairly high contact resistance Fairly high abrasiveness
Stationary Motors with Slotted Commutators....	Medium current carrying capacity Medium contact resistance Slight abrasiveness
Generators and Rotaries with Flush Mica.........	High current carrying capacity Fairly high contact resistance Fairly high abrasiveness Self lubricating
Generators and Rotaries with Slotted Commutators	High current carrying capacity Medium contact resistance Slight abrasiveness Self lubricating

Brush Shunts.

Brush shunts, or "pigtails," are provided on brushes to carry the current from the brush to the stud, or from the stud to the brush. These shunts are necessary in all cases where the brush slides in a box or holder. They are not necessary in case the brush is clamped to the holder in a fixed position, or in case special provision is otherwise made to conduct the current from brush to stud.

Shunts are necessary with sliding brushes in order to prevent burning of the holder and the brush sides. Fig. 2 shows the desired current flow. If the shunt is defective the current will arc from the brush to the box, as indicated in Fig. 2. This will cause the interior of the brush box to be badly burned, in which case the brush may not move freely in the box. The burning of the brush sides, together with the burning of the box, will in time cause the brush to be too small for the box and sparking troubles may result as described in a preceding article.

A defective brush shunt will also cause a portion of the current to flow through the brush spring, as indicated in Fig. 2. The resulting heating of the spring will cause it to vary its pressure on the brush. This may lead to serious unbalance in current distribution between brushes.

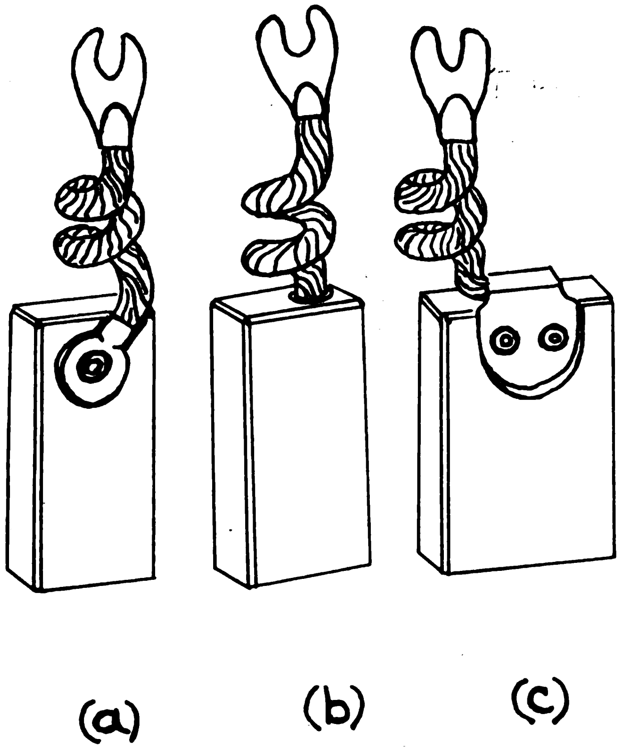

FIG. 3—Methods of attaching brush shunts to brushes. a—Shunt held in contact with brush by a spun rivet. b—Shunt attached to brush by copper cement which is tamped in hole in brush in which cable is inserted. c—Shunt attached to copper saddle, this saddle being attached to brush by rivets.

The shunt should be quite flexible in order that it may not interfere with the movement of the brush in the box. The necessary flexibility is obtained by the use of shunts made of many strands of small wire.

The shunt is commonly attached to the brush by riveting it to the brush with a specially designed type of rivet, or by cementing it to the brush with a special current conducting cement. It is important that the shunt should be attached to the brush in such manner as to make a good mechanical and electrical connection, and that this connection be maintained in good condition.

The design of many machines is such that there is considerable possibility of accidental grounds or short circuits due to the brush shunts coming into contact with other parts of the machine. In such cases the shunts should be insulated, glass or lava beads proving quite satisfactory for his purpose. In some cases asbestos sleeving is found to be more satisfactory. This is especially true in the case of enclosed motors which are operated at high temperatures.

The shunt should, of course, be so attached to the brush that no interference will be offered by it to the movement of the brush in the box or to the action of the brush spring.

Commutation Troubles and Remedies.

It is often found that a change in grade of brush will prove quite helpful in the solution of certain commutation and sparking troubles. Care must be exercised in making such changes, however, since a change in only one property may be required to eliminate existing troubles while a change in other properties may lead to the development of other troubles.

TABLE III

BRUSH CHANGES WHICH OFTEN PROVE HELPFUL IN THE SOLUTION OF COMMUTATION PROBLEMS

Trouble	Change to brush having—
Chatter, due to vibration......	Greater lubricating qualities
Chatter, due to rough commutator	Greater polishing action
Chatter due to dry commutator	Greater lubricating qualities
High mica, due to excessive local currents..............	Higher contact resistance and greater abrasiveness
High mica, due to sparking from other causes..........	Higher current carrying capacity and greater abrasiveness
Burning and pitting of entire brush face.................	Lower contact resistance and higher current carrying capacity
Burning of portion of brush face	Higher contact resistance
Deposit of copper on portion of brush face..............	Higher contact resistance
Deposit of copper on entire brush face.................	Higher current carrying capacity

Table III outlines certain changes in brush properties which may assist in reducing or eliminating commutation troubles.

It is believed that these suggested remedies need not be discussed in detail here in view of the preceding discussion of brush properties and the discussion of causes of commutation troubles given in preceding articles of this series.

It should be noted here, however, that a simple change in brush grade cannot be expected to eliminate sparking troubles under all conditions. Most sparking troubles are due to causes not directly associated with the grade of brush used, hence the troubles must be remedied by eliminating the direct cause of the trouble. The solution of the problem is often made less difficult, however, by changing the grade of brush as indicated in the table.

Satisfactory operation of brushes, and freedom from sparking troubles cannot be expected unless attention is given to the maintenance of the commutator. The maintenance and repair of commutators will **be discussed in the next article of this series.**

Comparison of Open-Hearth Furnaces

The Author Briefly Points Out the Basic Operating Conditions That Must Be Evaluated When Making a Comparison of Open-Hearth Furnaces of Various Sizes

By STEWART J. CORT†

A GREAT many valuable papers have been presented before this institute dealing with the design and construction of open-hearth furnaces, the chemical reactions, thermal balances and other interesting technical problems that the open-hearth process presents. As the subject of this paper is so broad, I have been obliged to limit my treatment of it in order to give more particular attention to commercial, rather than technical, considerations.

Today with the increasing demand for greater production per furnace and the necessity of securing lower operating costs, there has been a concerted drive on the betterment of open-hearth construction and operation. In making this comparison, I will endeavor to make it a fairly composite picture of the industry, and I wish to thank the different companies that have so kindly co-operated with me in order that I might be able to accomplish it.

In making a survey of the sizes and operations of different furnaces, there is found to be such a wide variation in tonnage produced, and in costs, even on furnaces of equal capacity, that it is impossible to make an intelligent comparison unless the operating details of the individual plant are taken into consideration. It will, therefore, be necessary to briefly point out the basic operating conditions that must be evaluated when making a comparison.

The canvass has brought out that practically all operating superintendents are thoroughly conversant with existing variations in the best open-hearth practice. It is assumed, therefore, that the construction of a given furnace, the application of the fuel to it, and the operations of making and teeming the steel are within the control of the operating superintendent. It is further assumed that each superintendent is following what he considers the best practice, and these points are consequently eliminated from discussion in this paper.

There are three things that directly affect open-hearth production and costs, irrespective of the size of furnace, to be considered in the following order:

Physical Layout.
Materials Used.
Grade of Steel Manufactured.

Physical Layout.

Of all the open-hearth plants in the country there are practically none that are duplicates. In the majority of the older plants the open-hearth furnaces were built to take the place of Bessemer converters, and in a great many cases the rolling mills were built first and the steel producing units added later. In others, where additional capacity was desired, furnaces were added to the existing line, or a new plant built in any available space.

With this method of growth, the engineer in a great many cases has been forced to make the layout suit the existing conditions, with the result that each individual plant has certain physical handicaps which must be duly weighed in making a comparison. An outstanding difference between plants is often not so much the actual time required to make a heat of steel as the difference in time lost through delays. The principal causes of delays are as follows:

Stocking and Charging — As the number of furnaces built in a line increases, the lost time increases proportionately, due to intereference in charging and in the placing and removal of cars. The necessity for adequate and frequent approaches to the charging floor, storage space for assembled heats, and ample trackage and switching facilities in the stockyard, are forcibly brought out in the comparison of furnace tonnages. The furnaces showing the greatest tonnage increases are those with the best charging advantages.

Casting—The pit or casting floor is one of the serious holding points in some of the older and more congested plants. The inability to prepare and place the proper mould equipment, especially in shops doing a wide range of work, such as bottom pouring, inverted and hot top moulds, etc., make it difficult to follow mill schedules and necessitates the holding of heats in the furnace with the aftermath of furnace bottom trouble.

Gas Producer Location and Flue Layout—The location of the gas producers and the length of flues play a very important role in the fuel ratio and lost time.

Furnace Rebuilding and Repairs—The cost and time of furnace rebuilding must be considered under plant layout. The plant that has not been provided with means of disposing of the material in cleaning out a furnace and in the delivering of refractories direct to the furnace, faces a direct handicap of five to ten cents per ton on labor and requires 20 per cent longer time in rebuilding, which means lower tonnage production.

Water—The item of water enters into cost of repairs and the effectiveness of the water-cooling that can be employed on a furnace. The inland steel plants, depending on local streams or rivers, have to contend with sediment and acidity in the water, which cause more frequent replacement of water-cooling devices and piping, due to blockage, burning out and corrosion.

Materials Used.

There is nothing in the operation of an open-hearth plant that gives as much trouble and affects the production and costs to such an extent as do variations in the materials used, and still they are usually given the least consideration when comparisons are being made.

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*Paper read before the American Iron and Steel Institute, at New York, May 21, 1926.

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These materials will be mentioned as follows:

Pig Iron.
Scrap.
Limestone.
Ore.
Fuel for Melting.

Pig Iron—The problem of securing the proper quality of pig iron for use in the basic open-hearth process is one of such vital importance that it deserves a much closer study than it has received in the past. It is too often assumed that the open-hearth is able to accomodate itself to any grade of iron, but experience has demonstrated that the range is very limited.

It is an axiom that the tonnage an open-hearth furnace produces and the yield from the ingot vary directly with the uniformity of the blast furnace operation. This has been the universal experience of steel makers and in making a study of the industry as a whole for this paper, without exception the open-hearth plants making the best showing were those receiving the best iron.

Today the steel maker is called upon to produce a higher grade product than ever before in the history of the industry. From the open-hearth furnace to the finished product a conversion cost of $18 to $20 is made, and using a 50 per cent metal charge, $36 to $40 is spent for every ton of pig iron used.

The majority of steel plants use all the iron the blast furnaces produce, regardless of the chemical analysis and phiysical condition of the iron. For example, one plant has found that whenever the sulphur and silicon in the iron varies beyond desirable limits and the casting temperature of the blast furnace drops with improper slag separation, the time of making heats in the open-hearth furnace increases 15 per cent over normal and the yield on the finished steel at the mills drops 5 or 6 per cent under normal. In some cases, it is very difficult to make the scheduled grade of steel, which causes a delay to the rolling mill by compelling diversion to stock of the unsatisfactory heat, and this delay is clearly due to unsatisfactory blast furnace operation.

The conversion cost put on the iron after leaving the blast furnaces, as shown above, is so large that any act which interferes with the quality of the iron, so as to increase the subsequent conversion costs, is adding materially to the total cost of the finished steel. Thus, slight savings that may be made in the coke cost, such as changing the coal mixture to use a cheaper quality of coal; or changing the screens so as to admit smaller sizes; or changing the quantity charged so as to lower the fuel ratio; or reducing the amount of flux to decrease the cost of burden; or whatever other apparent economy interferes with the rapid production of chemically and physically suitable iron, are much more than offset when the total cost of steel is reckoned by the consequent conversion losses in the steel plant.

The manganese content of the pig iron is an item that must not be overlooked in making a comparison. This feature has been presented to the Institute several time and needs no comment except that the plants using iron with 1.60 per cent manganese and over are showing a higher production and yield than those where iron with .90 to 1.10 per cent manganese content is used.

The percentage of hot metal charged in the different plants on stationary furnaces varies from 38 to 65 per cent, depending entirely on the amount available and the difference in the price of metal and scrap.

A 50 per cent metal charge is generally recognized as the best mix for all around practice, a higher metal charge giving higher conversion cost, due to lower ingot yield. The plant running on a fairly constant charge has a distinct advantage over one that is constantly changing the per cent of metal, due to the helper being able to secure a much more uniform melt.

Scrap—The quantity and quality of melting scrap used must always be taken into consideration when comparing the tons per square foot of hearth area and coal equivalent for melting.

The furnace charging all heavy melting home scrap will be able to charge in forty minutes to one hour, while the furnace using miscellaneous purchased scrap will require two and one-half to three hours, having to charge two or three times, melting down between charges, which automatically lowers the production 15 to 20 per cent and increases the coal equivalent about an equal amount.

The roof life of the furnace is correspondingly lower on this miscellaneous scrap charge, due to the channeling effects of the flame when the furnace is filled with scrap, which, of course, increases the furnace rebuilding costs.

Limestone—The variation in limestone is something that cannot be overlooked. Limestones with practically the same chemical analysis behave quite differently in forming the slag. An extremely refractory stone will require 30 to 40 minutes longer time to shape up the finishing slag.

Ore—There is a wide variation in the grade of ore used by different plants, both as to size and chemical analysis. The plant using a low silica, clean, lump ore enjoys a decided advantage, both in the time required in working the heats and in time lost on account of bottom and bank trouble.

Fuel—Where producers are used, the quality of gas coal used, both as to its chemical analysis and physical condition, must be taken into account. A plant using a high-volatile low-sulphur and low-ash coal that has been screened free of slack, has a 10 per cent or greater advantage, both in tons of steel produced and coal per ton of ingots, over the plant with the same gas producer capacity, using high-ash, high-sulphur coal that has not been screened.

The plants using low-sulphur fuel-oil for melting have a decided advantage on a high scrap charge, due to the elimination of sulphur trouble in the steel and being able to carry a lower lime ratio. With high metal charges, this advantage is lost, due to the slag foaming and not clearing up as rapidly as with producer gas.

Tar as a fuel gives excellent results but has the disadvantage of filling up the regenerators more rapidly than other types of fuel.

Coke oven gas and natural gas, whether used alone or in combination with oil or tar, make a most excellent fuel for rapid work and allow a simpler construction than that needed for producer gas. Rebuilding costs will also be lower.

Grade of Steel Manufactured.

One of the most difficult problems in making a fair comparison is that of making the proper allowance for the grade of steel being manufactured.

The survey made in securing the data for this paper brought out some very interesting facts. For example, two plants, making steel of the same chemical analysis and for the same general use, differ very widely in time taken in finishing up the heat. One plant used 5 to 6 per cent limestone and the other 10 to 11 per cent on nearly the same charge and grade of scrap, pig iron and fuel, which is equivalent of one to one and one-half hours in the time of heat, the variation being accounted for by the difference in method of rolling the ingots and the ability of the rolling mills to divert the steel over a wide range of products. The plant called upon to make 100 per cent high-grade product, with no outlet for questionable heats of steel, cannot afford to take the chances that another plant with diversified product can take without paying too high a penalty on the mill yields.

The quantity of ferro-manganese, whether added to the bath or as a ladle addition; the time of ore additions; and the shaping up of the finishing slag in order to eliminate as far as possible the unbalanced reactions, differ greatly between plants.

The rating of an open-hearth plant, in the final analysis, should be on the tonnage of finished product shipped to the customer, rather than on ingot product, for the mill yields vary widely between different plants. On some products the variation will run 4 to 5 per cent and on others as high as 7 to 8 per cent. The method of rolling, the diversity of orders, and whether the steel is shipped to outside customers or finished by the same company, have a definite bearing on the precautions necessary in the open-hearth department.

Bearing in mind these variable factors that enter into an open-hearth operation, we can better understand why there is a difference of as much as 25 per cent in tonnage between plants with the same nominal hearth area and tapping heats of the same weight.

Today it is impossible to pay much attention to the nominal rated capacity of a furnace, the only measure being the size of heats tapped. The size of steel ladle, crane capacity and strength of crane runway are usually the governing factors in the weight of heats. Table I gives the general increase in furnace capacity which seems to be now prevalent.

TABLE I

Nominal Rating		Rated Hearth Area	Weight of Heats Tapped
Stationary, Basic	50-ton	370 to 400 sq. ft.	60 to 65 tons
Stationary, Basic	60-ton	440 to 475 sq. ft.	70 to 80 tons
Stationary, Basic	75-ton	500 to 540 sq. ft.	80 to 110 tons
Stationary, Basic	90-ton	550 to 600 sq. ft.	110 to 150 tons
Stationary, Basic	100-ton	650 sq. ft.	140 tons
Tilting, Basic	200-ton	675 sq. ft.	225 tons
Tilting, Basic	250-ton	775 sq. ft.	250 to 270 tons
Tilting, Basic	300-ton	825 sq. ft.	250 to 400 tons

During the past 10 years there has been a decided increase in efficiency of open-hearth operation all along the line, so that today the production per furnace has been raised about 30 per cent and the plant that has failed to achieve this increase has not followed the general trend of the industry.

This increase in production cannot be credited entirely to the larger heat but to a general improvement in materials charged, better valve and water-cooling, furnace design and a general betterment of auxiliary equipment.

The plants that have failed to benefit by increased size of heats are those that have increased the hearth, and not the regenerators and valve areas to meet the increased charge.

I wish to make a direct comparison between stationary furnaces under 90-ton capacity, stationary furnaces tapping 90 tons and over, and the large tilting furnaces, as to the quality of product, the number of tons per hour per thousand square feet of hearth area, and the cost above net metal.

In attempting to tabulate the data collected from a large number of plants, I find the figures are so misleading that they would simply result in confusing the comparison unless they are accompanied by exhaustive explanations. This is due to the variations pointed out in the first part of this paper and the methods employed in keeping plant records and in making up cost sheets. For example, there is no uniform way of computing hearth areas, furnaces with exactly the same exterior dimensions reporting a difference of 10 to 15 per cent in hearth area; and there is no standard method of computing operating hours.

The records for melting, whether coal, gas or liquid fuel, are not exact, often being estimates for the unit in question.

The distribution of producing labor against companies and parts of the operation varies greatly between companies and also between different plants in the same company. Repair and maintenance costs, both for material and labor, are other items lacking uniformity. In some cases, repairs are charged direct against the tonnage produced that month; in others, on provision accounts; and in still others, against the capital account, considering the material replaced as having been written off.

The methods of computing the ingot yield of open-hearth furnaces vary widely. Some plants use the actual weights of materials charged into the furnace and the actual weight of ingots produced; while other plants use estimated weights for the scrap produced by the rolling mills, charging this weight to the open-hearth, and the ingot production is also estimated.

A general summary will first be given, trying to interpret as accurately as possible the different operations in different plants. There will also be shown the exact figures of a year's operation of furnaces tapping 80 and 110-ton heats in the same plant, where the same grade of steel is made and all records and costs are kept on exactly the same basis.

Quality of Steel Produced—There was at one time a serious doubt in the minds of steel makers whether as good a grade of steel could be produced in a large furnace as could be made in the small furnace. The reports on this question are unanimous that equally as good quality steel can be made with the large heats as the small.

One maker of sheets has gone from 110 to 150-ton heats with no change in mill practice. Another maker of high-grade carbon and alloy steel has increased his heats from 80 to 100 tons and the results are so favorable that he is now preparing to make 125-ton heats. Another firm reports that practice from 110-ton heats against 80-ton heats showed 0.4 per cent better yield on the mills, taken over an entire year's operation.

The large furnace has been in use for a sufficient time to definitely establish that there is nothing to be feared as far as quality is concerned. The large heat assures better pouring practice when the proper design of ladle is used, as the loss of heat by radiation is less and more time and care can be taken in teeming.

Tons Produced Per 1000 Square Feet of Hearth Area Per Hour—Only yearly averages under normal conditions can be taken as a comparison. Stationary basic furnaces, tapping between 60 and 90-ton heats, vary from 12 to 19 tons per 100 sq. ft. per hour; with the major portion of the furnaces, that are more nearly on an equal basis, between 13.5 and 14.5 tons.

The figures of 14 tons per 100 sq. ft. per hour for furnaces tapping 80 to 90-ton heats can be taken as a good standard operation. There are, however, a few notable exceptions to this: One plant tapping 60-ton heats maintaining 16 tons per 1000 sq. ft. per hour; and another tapping 80 tons, running 19 tons.

The coal equivalent for the 14 tons per 1000 sq. ft. plant tapping 80 to 90-ton heats, is about 550 pounds and the monthly production runs between 5,200 and 5,600 tons. Stationary basic furnaces tapping 90 to 150-ton heats vary from 13 to 17 tons per 1000 sq. ft. per hour, the plants more nearly comparable falling between 15 and 17 tons. The figure of 16 tons for furnaces tapping 110 to 125-ton heats can be taken as good standard practice, with coal equivalent of 500 pounds, and monthly production running between 6,500 and 7,000 tons.

Tilting furnaces with 200 to 300 tons capacity, running on pig iron and scrap, vary in method of tapping. In some cases single heats are tapped and the furnace not drained, while the common practice is to drain the furnace each time, taking two, three or four heats, depending on the size of furnace and the ladle capacity. The comparison of tons per 1000 sq. ft. per hour varies widely, running from 12 to 20 tons. The two plants most nearly comparable are making as follows: One with 200-ton furnaces produces 9,000 tons per month with 500-pound coal equivalent, while the other with 300-ton furnaces produces 9,500 tons per month with approimaxtely the same coal equivalent.

As would be expected the large furnace has the greater hourly capacity and better fuel efficiency.

Cost Above Net Metal--Cost above net metal is a much better figure to use for comparative purposes than total conversion cost, as it eliminates largely the variation due to different percentages of pig iron and scrap charged and also variations in the cost of these commodities.

TABLE II

	75-ton Stationary	200-ton Tilting
Weight of heat	82.8 tons	*2 of 107 tons
Average production per furnace per year	59,538 tons	110,639 tons
Tons produced per 1000 sq. ft. per hour	13.9 tons	19.3 tons
Coal used per ton	587 pounds	496 pounds
Time of heats, tap to tap	12 hrs. 7 min.	*8 hrs. 15 min.
Charge:		
Hot metal	49.89 per cent	22.30 per cent
Cold metal	1.73 per cent	.15 per cent
Steel scrap	48.25 per cent	76.63 per cent
Ore	4.11 per cent	.01 per cent
Bottom delays per year per furnace	236 hrs. 9 min.	15 hrs. 10 min.

*Figured on single heats, as each ladleful carries a separate heat number.

These figures in a great many cases are rather surprising in that the larger furnaces do not show the saving expected although they have the advantage in heating, labor, mainteance and rebuilding costs, the difference coming in the producing labor and rebuilding costs, which is not a reflection on the large furnace but rather on the method of operating.

The figures in Table II are for an Eastern steel plant for the year 1925, the comparison being between 75-ton basic stationary furnaces and 200-ton basic tilting furnaces, the tilting furnaces charging 215 tons and tapping two 107-ton heats, draining the furnace each tap.

The above figures give a definite idea of the nature of the operation on each type of furnace.

The variation in the cost above net metal is given in Table III for the year's operation. All records in both shops were kept on the same basis, all materials were charged at the same price and the wage scale was such that like positions made the same earnings in both shops. The stationary furnace is taken as the base and all differences shown on the tilting furnace. Thus the large furnace made a saving of 79.8 cents per ton on cost above net metal, which equals $88,290 for the year per furnace.

TABLE III

Variations in Cost per Ton of Ingots
200-ton Tilting Furnace

*Fluxes	+$0.075
Heating	-- 0.302
Total producing labor	— 0.151
Total repairs and supplies (labor and material)	— 0.171
Furnace rebuilding	— 0.183
All other expense	— 0.066
Total	—$0.798

*Burnt lime was charged on tilting furnace and stationary used raw stone.

An outstanding feature is that the stationary furnaces averaged 236 hours, 9 minutes per furnace for the year on repairs to bottom, while the large tilting furnaces lost only 15 hours, 10 minutes per furnace for the year.

The biggest advantage of the large stationary or tilting furnace is the saving made in man power. The same furnace crew as is necessary on a 60-ton furnace handles a 125-ton stationary or 250-ton tilting furnace and does it with less effort, as the small furnace is tapping every 7 or 8 hours while the large furnace taps every 11 to 16 hours. This means less labor making bottoms, for while the large bottom requires a slightly longer time to make up, it has to be done less frequently; and the work of keeping up the large furnace is less, due to a relatively shorter flame and working easier on the outgoing ends.

There are two other points which I would like to discuss briefly, namely: The relative cost of construction of the various sizes of furnaces and their adaptability to the different percentages of pig iron and scrap that may be necessary for a plant to use.

Cost of Construction.

Figures in Table IV will not hold true in all localities due to varying cost of materials and of labor; but they can be taken as a fair criterion of the difference in cost at any given location.

These figures are based on stationary furnaces built six or more in a line, and tilters three or more in a line.

Much of the auxiliary equipment need not be considered; because stockyard, charging and casting cars, charging machine, floor cranes, gas producers or tar or oil burning equipment, metal mixers, mould yard and strippers vary very little with size of furnace. The ladle crane will vary, depending on capacity, from $60,000 for 100-ton to $100,000 for a 200-ton crane.

Assuming 60,000 tons as the yearly capacity of a 75-ton furnace and 84,000 tons as the capacity of a 100-ton stationary furnace, the ratio of production would be 1 : 1.40, and the ratio of building cost 1 : 1.25; while a comparison of a 100-ton stationary with a 250-ton tilting furnace, assuming 108,000 tons as the yearly capacity of the tilting furnace, the ratio of production would be 1 : 1.28 and the cost of building 1 : 1.72.

Size and Type of Furnace to Select.

The selection of the size and type of open-hearth furnace depends on the amount of molten metal available and the spread in price between scrap and pig iron.

The size of stationary furnace to adopt is limited by two factors: The capacity of the steel ladle, and the percentage of pig iron and scrap used. It is possible to build ladles, cranes and runways of very large capacities but the maximum ladle will probably not exceed 150 tons from our present experience. The 150-ton heat is handled successfully today, requiring a 200-ton ladle crane.

TABLE IV—COMPARATIVE COSTS FOR ONE FURNACE

Type of Furnace		Furnace with Foundation	Waste Heat Boilers	Building	Total	Difference over Preceding Type
Stat.	Tilt.					
60-T	......	$116,000	$25,000	$120,000	$261,000	......
75-T	......	145,000	30,000	130,000	305,000	$ 44,000
100-T	......	193,500	35,000	155,000	383,500	78,500
......	100-T	270,000	35,000	170,000	475,000	91,500
......	200-T	360,000	40,000	200,000	600,000	125,000
......	250-T	400,000	40,000	220,000	660,000	60,000

In designing a steel ladle of large capacity, it is necessary to keep the height of ladle as low as possible, in order to reduce the static head on the stream of steel in teeming the first ingots of the heat, and also to insure good stopper rod practice. The increase in size is best obtained by increasing the cross-section of the ladle. To exceed 150-ton capacity, the size of ladle and crane reach a point where they become unwieldy.

The most satisfactory size of nozzle for general work in pouring is 1¾ inch and should not exceed 2 inches. With the refractories now used for nozzles and stopper rods, 150 tons is about the maximum, when careful pouring is required; and in cases where small moulds are used with numerous shut-offs, 125 tons will probably be the limit.

The capacity of the bath of the stationary furnace can only be increased in size by increasing its length and by deepening the hearth, as the width is established at a maximum of 15 feet to 16 feet which is the limit at which it is possible for men to tap heats and rabble out holes in the bottoms and banks and properly maintain them.

The furnace which has increased its capacity by deepening the bath is definitely committed to a high scrap charge in order to secure maximum production, and the furnaces tapping the largest heats today are using only 38 to 42 per cent metal. With deep bath, oxidation is slower and it is difficult to carry the proper slag volume, which increases with the pig iron charged. It has been found that the time lost in oxidation on heats using more metal than is needed to give the proper melt, offsets the advantage gained by the larger heats. Or it may be stated conversely, that with a deep bath, less steel is exposed to the slag and therefore less pig iron is required.

The furnace running a 24 inch depth of bath will work very successfully on high hot metal charges. Increasing the capacity of the hearth by lengthening the bath and maintaining a relatively shallow depth for rapid oxidation has the disadvantage of requiring a bottom too flat for proper drainage to the tap hole, with the result of excessive delays in repairing it.

Today plans are being made to build 250-ton stationary furnaces, having a bath 43 feet by 16 feet with a depth of 37 inches, using a bifurcated spout tapping into two ladles. This type of furnace will be a melting process using a high scrap charge.

The largest stationary furnace built today has a bath of 47 feet by 15 feet and is designed for 140-ton heats. This furnace should work satisfactorily on high percentage of metal, providing it is possible to maintain the bottom.

The 250-ton tilting furnaces are coming into favor as a balance wheel in steel plants that have requirements for Bessemer steel. They are admirably adapted for high scrap charges when the maximum output of steel is not required, and can be used for duplexing when peak requirements are to be met. The operation of tilting furnaces is a good illustration of the effect of bath depth on rapidity of oxidation with various percentages of metal.

The largest producer of steel with tilting furnaces finds that 35 per cent of metal is the best charge and that 42 per cent is about the maximum for satisfactory tonnage. Another company running 200-ton tilting furnaces, with a 22 per cent metal charge, is able to produce 10 per cent more steel per furnace than a 250-ton tilting furnace with 60 per cent metal, and does it with 70 pounds of coal less per ton of steel produced.

A new plant is now under construction, in which are being installed 100-ton tilting furnaces for the manufacture of high grade steels. This type furnace has the advantage of freedom from bottom trouble and insurance of a uniform rate of tap, which are two very essential things in the making of alloy steels.

Summary.

In summing up, I would say that in trying to co-ordinate the data collected in order to compare the operations of furnaces of different capacities, such differences appeared that it was necessary to determine the variable factors; and I have tried to bring them briefly to your attention in this paper.

The capacity of an open-hearth furnace of any given size is so dependent on the nature of the materials charged, the kind of fuel used for melting and the quality of the product it is called upon to produce, that any comparison is worthless unless all these items are given the proper consideration. It is also necessary to standardize the methods of keeping open-hearth furnace production records and a uniform system of showing the correct distribution of costs in order that a comparison of the operations of different plants will not be misleading.

I wish to again emphasize that inherently there is no reason why as good steel cannot be made in a large furnace as in a small furnace.

The saving in man power in the operation of the large furnace is an important item, as more tons are produced per man with the accompanying lower labor costs.

From the standpoint of capital invested the 100-ton stationary furnace is the most economical to build and gives the most satisfactory results when the operation calls for the use of 40 to 65 per cent hot metal.

The large tilting furnace, while having the higher initial cost, can more than offset this by the saving in operating costs, providing it is possible to utilize it to the best advantage; that is, either on a high steel scrap charge varying from 60 to 80 per cent scrap, or using it in the duplex operation.

The large tilting furnace is best suited for a large steel plant which is equipped with sufficient soaking pit capacity to charge 250 to 300 tons of ingots at a time, while a small steel unit can be more efficiently operated if the ingots are received in small increments.

The large furnace, while it is able to produce at a lower cost, will not be able to entirely displace the 60 to 75-ton furnace in specialty shops; that is, shops making a wide range of alloy steels for the merchant trade where only small tonnages are required of a given composition.

Preliminary plans for the Fifth National Exposition of Power and Mechanical Engineering indicate that the coming event, which is to be held in the Grand Central Palace, New York City, from December 6 through 11, 1926, will be even larger and more inclusive than the Fourth Exposition.

Three entire floors of the Palace have been sold to exhibitors and a portion of the fourth floor. Contracts have been signed with 332 manufacturers of all types of mechanical and power plant equipment. The manner in which this important annual event is serving all of the mechanical industries is well illustrated by the diversity of the exhibits at the previous show. About 140 exhibitors showed products that are of importance to the heating and ventilating field and 75 showed machinery which could be used to good advantage in the machine shops of the country. The total number of exhibitors was over 400 and while a large number devoted space to power generating equipment, the entire show gave a great deal of exceedingly valuable new information of general interest to all types of industry.

An important innovation in the conduct of the coming exposition will be the addition of several exhibits essentially educational in character which point out the tremendous advances that are being made in mechanical design and construction.

The exhibition managers are assisted in the conduct of the exposition by an Advisory Board made up of representatives of technical societies in the mechanical field and also representatives of large users of mechanical equipment who are interested in maintaining the high standing of the exposition.

Large Welded Trusses Under Test

A series of four roof trusses was tested to destruction at the Engineering Laboratory of The Linde Air Products Company, Buffalo, N. Y., during the week of May 10; the culmination of a year's intensive study of the proper application of oxy-acetylene welding to the fabrication of steel structures.

As a first step, studies were made of various types of joints in various kinds of steel shapes. A few of the most promising schemes were then built into typical truss intersections, and proper jigs built to load these joints to destruction. Unit stresses for weld metal in tension, compression and shear were determined by this means. The variety known as the "plate insert joint" was shown to have marked advantages.

Next a 40-foot roof truss was designed and built of conventional angle-iron sections, using the information gained by this preliminary work. In testing, very elaborate framework was necessary to give the upper chord of the truss the lateral support it would receive when placed in a building. Platforms were hung from each panel point and loaded with pig iron.

At definite increments of load the stresses in each member were measured by an extensometer. At double design load, each welded joint was vigorously pounded with a heavy hammer. At three and one-half times the design load, the truss failed by buckling in the upper chord—no distress at any welded joint was in evidence. At the time of failure the truss designed for 21,000 pounds load, was carrying 75,000 pounds of pig iron.

Having thus demonstrated the soundness of the underlying methods, four trusses were prepared for comparative test. One was designed and built by a leading structural shop; another was welded by the Linde Company, using members of the same size from the same mill rolling; the third was designed to have the same strength as the riveted truss, but since the oxy-acetylene welded point allows a better placement of the metal, it was materially lighter in weight. A fourth truss was welded of tubular sections.

A summary of the final result follows:

Style	Weight Lb.	Total Load at Failure Lb.
Riveted Truss	1,161	62 000
Welded Truss of equal weight...	1,150	72,000
Welded Truss of lighter weight..	1,079	70.000
Welded Truss of tubular sections	916	63,000

All trusses failed by buckling of the top chord, a compression member. In no instance were there any signs of distress at a joint.

These tests were made under observation of engineers from the Pittsburgh Testing Laboratory, and in the presence of several independent observers and representatives of Governmental departments. More detailed results will be available as soon as the formal report is made by the Pittsburgh Testing Laboratory.

Vote for Equipment Merger

Shareholders of the Railway Steel Spring Company have approved the plan to merge with the American Locomotive Company under terms of a proposal recently announced by the directorates of the two concerns. The plan also has been approved by stockholders of the American Locomotive Company.

The Influence of Mold Wall Thickness*

The Influence of Primary Crystallization and Time of Solidification Are Examined in Three Different Mold Sizes With Decreasing Wall Thickness

By DR. ING. F. LEITNER

Translated by Richard Rimbach†

LITTLE has been published as yet in regard to the choice of wall thickness of cast ingot from molds and the influence it has on the ingot. One usually makes use of the old rule that the section of the ingot and the section of the wall should be alike in the upper part of the mold.

For the quick solidification of the lower part of the ingot, the walls must increase in thickness toward the bottom. E. Gathman[1] further increases this relation in favor of the section of the mold to 1:1.4 for the upper part and recommends giving the lower part of the mold to a heat absorbing capacity six times as large as that of the quantity of steel. He gives preference to the heavy walled molds since they quickly form a strong skin of solid steel which counteracts the formation of cracks. A. W. and H. Brearley[2] find on the other hand that there is no considerable difference as to the time required to form a sufficiently strong skin with heavy and light walled molds.

Oberhoffer[3] has determined to what extent the primary crystal of Lebeburit steels are larger cast in sand than in cast iron molds. With this as a basis Rapatz[4] has examined the influence of the wall thickness of the mold on high speed steel. He believes that thick cast iron molds do not produce a finer primary grain than medium heavy molds. J. Priestly[5] claims to have noticed a favorable influence in the ingot with a relation of ingot section to mold section 1:3.

The object of this investigation was to clear up the influences of wall thickness on the small ingot-sections. The investigation was divided into two parts. First, to determine the upper limit of the wall thickness beyond which the solidification is no longer influenced, and secondly, to investigate the results produced by decreasing the wall thickness. The points to be taken into consideration herewith are the primary formation of crystals, the velocity of solidification, the durability of the molds and their heating.

The following ingot sections were chosen: 140 mm. round, 230 mm. round and 250 mm. square. Steel high in manganese and carbon was selected for the determination of the velocity of solidification. The peculiar property of this alloy, is to crystallize with comparatively coarse crystals: (High crystallization speed—small number of grains). In the one case a good photograph of the crystal arrangement is given, in the other case the time of solidification is clearly shown. Cross-section specimens for the primary etching were taken from the center of the ingot and etched with 5 per cent nitric acid[6]. For the determination of the solidification taking place after casting, the cast iron molds were turned over at certain intervals and the solid outer zone of the ingots was measured.

The wall thickness of the 140 mm. round mold were 55, 45, 40, 30 and 25 mm. The casting temperature of the chrome nickel steel was about 1,650 deg. C. and the casting took place at a casting velocity of 0.6 meters drop per minute. All tests were repeated three times and the conditions were alike for the tests shown in the etched cross sections, Figs. 1 to 4. In Fig. 1 (wall thickness 45 mm.) there is an absolute transcrystallization; the size of the crystal decreases toward the interior. Fig. 2 and 3 (wall thickness 40 and 30 mm.) respectively show the almost same crystallization as Fig. 1 except that the crystals in the core seem to be oriented less and consist of finer grains. The core is larger in Fig. 3 than in Fig. 2. In Fig. 4 (wall thickness 25 mm.) the small transcrystallized outer zone is followed by a zone of finer grain adjacent to large but slightly oriented crystals. The wall thickness of 55 mm. gave the same structure as Fig. 1.

The uselessness of an increase of wall thickness over 45 mm. is proven for this ingot size. With the thinner molds their influence is at first only gradually recognizable. The outer zones go through the same under-cooling process and therefore show the same size crystals. With a wall thickness of 25 mm. the influence of under-cooling is suddenly reduced by the heating of the mold. At the moment of solidification of the transcrystallized outer zone the mold wall had reached a temperature of 390 deg. C.

Comparing the four sections, Fig. 3 is thought to be the most favorable due to the finer core crystals. At the limit of the influence of pronounced under-cooling, that is at the end of the transcrystallized zone, small crystals are almost always formed. Their origin is traced to the greater movement in these sections, which results in an increase in the number of grains. Probably it can be traced to the gases which separate out during solidification and are forced toward the center into the zone of free growing crystals where they act along the transcrystallized zone which is already solidified. With thick walled molds the ingot seldom shows these arrangements. The tendency of the large crystals is to grow at a greater rate than the influence of degasification. The crystallization, therefore, is influenced by the ability of the mold to absorb heat, which governs the velocity of transition of some under-cooled sections in the ingot. It reaches the upper limit of influence with a certain wall thickness.

Further tests affirmed the results of the first test. The 230 mm. round ingots were cast in molds with 65, 55, 45, 35 and 30 mm. wall thickness under the same conditions as the first tests. Fig. 5 (wall thickness 55 mm.) shows a section of the ingot with a pronounced transcrystallization structure which in Fig. 6 (wall thickness 45 mm.) extends toward the center. Figs. 7 and 8 (35 and 30 mm. wall thickness respectively) show agreement with Figs. 3 and 4. The reason for the different crystal formation is given above. The ingot section with 65 mm. wall thickness is similar to Fig. 5 and the limit of influence of the wall is recognizable.

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*From Stahl und Eisen, May 13, 1926, pp. 629-631.

†Metallurgist, Pittsburgh, Pa.

[1] Trans. Am. Soc. Steel Treat. May, 1924, pp. 158-69.

[2] Ingots and Ingot Moulds (London, Longmans, Green & Company, 1918).

[3] Stahl und Eisen, 1922, p. 1240.

[4] Stahl und Eisen, 1924, p. 1137.

[5] Trans. Am. Inst. Min. Met. Engrs., 1923-4, pp. 73-135.

[6] Bericht Werkstoffsausschuss, Verein deutscher Eisenhuettenbluete., No. 57, 1925.

For the 250-mm. square ingots the molds were reduced in steps from 75 to 65, 55, 45 and 35 mm. Fig. 9 shows the etched section of an ingot which was cast in a mold with three different wall thicknesses. The top was adjacent to the wall of 75 mm. thickness, the bottom to 55 mm. and the two sides to 65 mm. This photograph shows that on the sides, neither the size of the crystals seemed to be changed nor a displacement of the cutting lines of the transcrystallization sections has occurred. Whereby it is plainly proven that for this size of ingot, the influence of under-cooling for a wall thickness over 55 mm. remains absolutely the same and velocity of solidification must be identical in all cases. The occurrence of shrinkage cavities in the center is remarkable. The crystal orientation is slightly delayed with the reduced mold wall thicknesses as shown in Fig. 7 and attains in Fig. 10 (wall thickness 35 mm.) the more desirable formation core.

It is of especial value to determine if the wall thickness of 30 mm. with 140 mm. round ingots and 35 mm. with both the 230 mm. square ingots caused a considerable increase of the time of solidification. The primary crystallization indicated that no essential difference existed. This was confirmed by turning the molds at certain intervals after casting was completed. Fig. 11 shows the sections of the 140 mm. round ingots (left, mold with wall thickness of 45 mm. right of mold with wall thickness 30 mm.), which were turned after 5 minutes and punctured 100 mm. below the dead holes. They are almost alike in size. Since such ingots were almost completely solid after 6 minutes, there can be only a very small delay of the solidification of the ingot by the thin walled mold. The same method was applied with the 230 mm. round ingots. The ingots turned over after 9 minutes gave 820 cc.

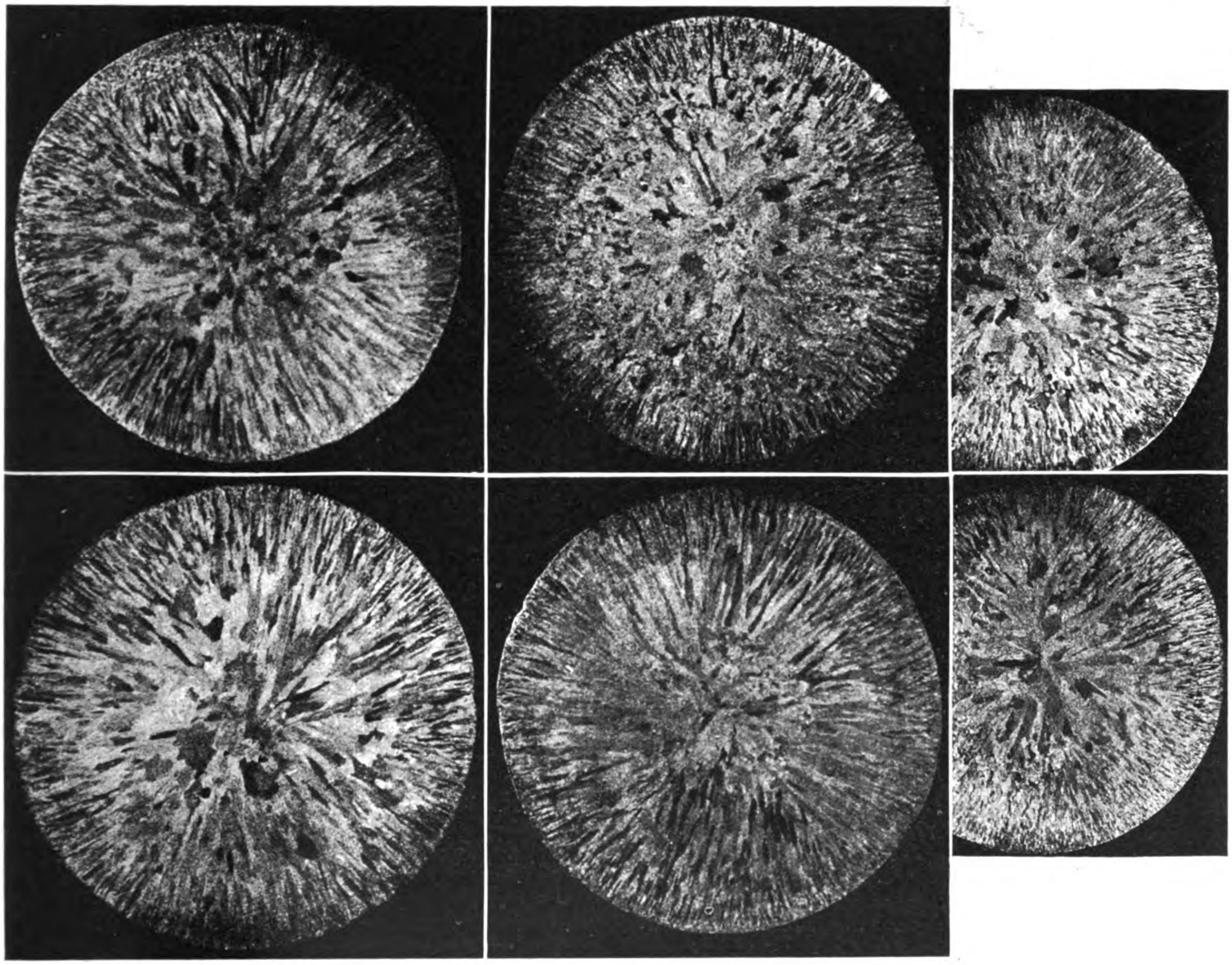

FIG. 1 (Lower Left)—140 mm. diameter ingot; mold wall thickness 45 mm. x 0.5. FIG. 2 (Upper Left)—140 mm. diameter ingot; mold wall thickness 40 mm. x 0.5. FIG. 3 (Lower Center)—140 mm. diameter ingot; mold wall thickness 30 mm. x 0.5. FIG. 4 (Upper Center)—140 mm. diameter ingot; mold wall thickness 25 mm. x 0.5. FIG. 5 (Lower Right)—230 mm. diameter ingot; mold wall thickness 55 mm. x 0.25. FIG. 6 (Upper Right)—230 mm. diameter ingot; mold wall thickness 45 mm. x 0.25.

of liquid steel for the wall thickness of 55 mm. and 1,085 cc. for the ingots from the 35 mm. mold. The differences are not large. This scarcely proves the supposition that the thinner molds cause greater segregations.

As to the durability of the molds no differences have shown up so far. No decrease in life need be feared as derived from the comparison of the durability of large molds with thick and thin walls. A good cast iron mold with a heavy ring at the top and bottom part of the casting aids considerably.

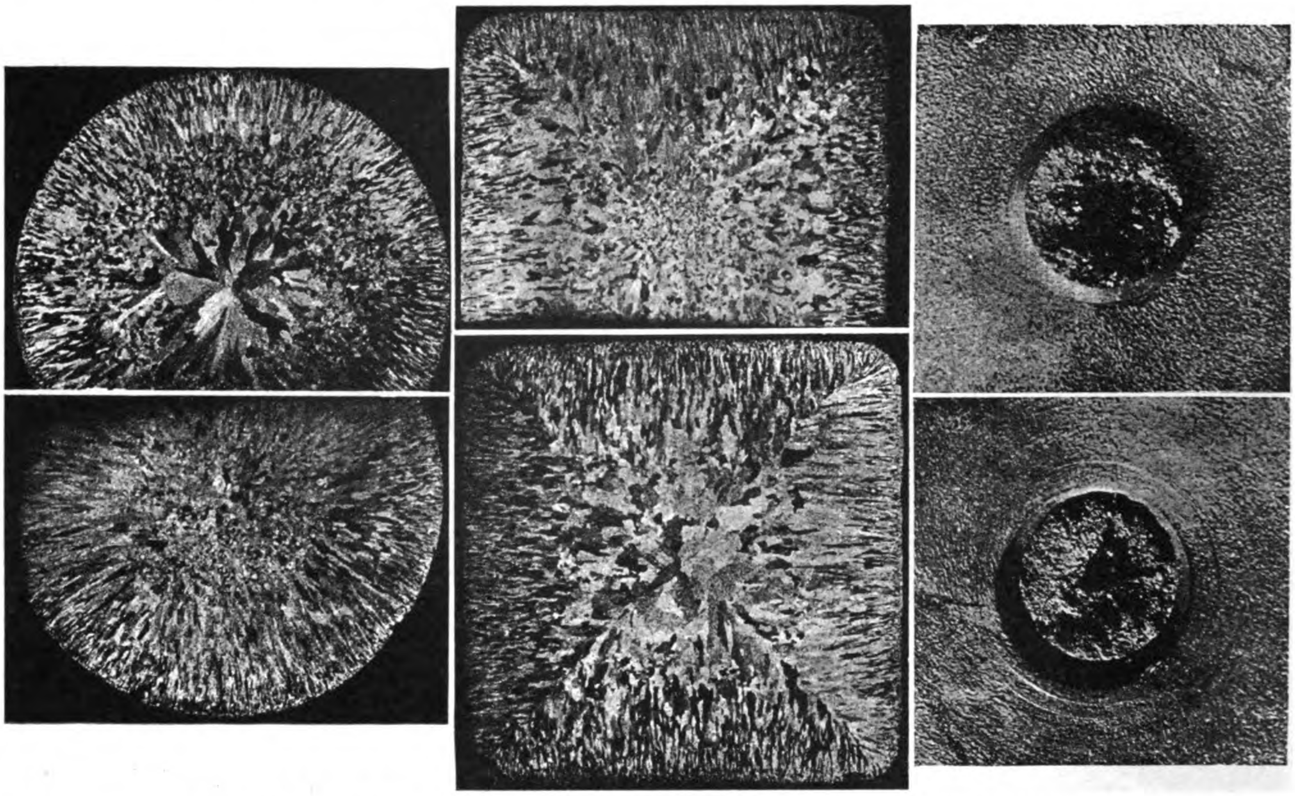

FIG. 7 (Lower Left)—230 mm. diameter ingot; mold wall thickness 35 mm. x 0.25. FIG. 8 (Upper Left)—230 mm. diameter ingot; mold wall thickness 30 mm. x 0.25. FIG. 9 (Lower Center)—250 mm. square ingot; mold wall thickness, upper 75 mm., lower 55 mm., left and right 65 mm. x 0.25. FIG. 10 (Upper Center)—250 mm. square ingot; mold wall thickness 35 mm. x 0.25. FIG. 11 (Lower and Upper Right)—140 mm. diameter ingot after 5 minutes solidification. x 0.25.

The heating of the mold after casting the 140 mm. round with 30 mm. wall, and the 240 mm. round and 250 mm. square molds with 35 mm. walls in no instance reached 750 deg. C. Although the inner zones are higher in temperature they do not exceed the allowable limit of heating. According to Brearley it is 200 deg. below the melting point of the mold material.

These tests show that for ingot sizes with a diameter of 140 mm. wall thicknesses of 30 to 35 mm., and for 230 to 250 mm. in diameter, 35 to 40 mm. are advisable. An increase of the wall thickness for the cases discussed of over 45 and 55 mm. respectively, has no influence either upon the crystallization or the velocity of solidification. The increase in crack formation assumed by Gathman ingots with thin walled molds is nullified by the results of the previously indicated lower limits of the wall thicknesses for these ingot sizes. However, they have the advantage that the core of the ingot is largely fine grained, which is favorable from the point of view of crystal formation and segregation of impurities. A further advantage is the lower cost.

The crystal formation can furthermore be changed by chemical composition, casting temperature, casting velocity and degree of fluidity. By the consideration of these individual circumstances separately a picture can be formed of the transcrystallization presumably occurring at the other zone and the primary crystallization. Without doubt, it would be of significance to continue similar tests on larger ingots.

The influence of primary crystallization and time of solidification are examined in three different mold sizes with decreasing wall thickness. Medium walled molds have the advantage, giving a better crystal development, approximately equal time of solidification and are less expensive than the heavy molds.

Krivobok to Study Recrystallization of Metals

Dr. V. N. Krivobok, Associate in the Bureau of Metallurgical Research of Carnegie Institute of Technology, has been awarded a grant of $500 by the Iron and Steel Institute of Great Britain to assist him in carrying out a photomicroscopic study, of recrystallization of metals after cold-working, according to an announcement. Public announcement of the award, which comes from the Carnegie Research Fund of the Iron and Steel Institute, was made at the annual meeting of the Institute in London, on May 6 and 7, 1926.

Dr. Krivobok has been a member of the staff of the Bureau of Metallurgical Research of Carnegie Tech since its organization by President Thomas S. Baker two years ago.

Safety Work in the Steel Wire Industry*

The Author Mentions Some Practical Methods Employed in the Steel Wire Industry to Attain a Reasonable Measure of Safety—Flexible Program Recommended

By CHARLES C. McDONALD†

MY intention in this paper is to point out some of the practical methods which have come under my observation in attaining a reasonable measure of safety results in the steel wire industry. In constructing a program for accident prevention work in the plant by which I am employed I have assumed four basic premises:

1—That accident prevention is an integral part of plant operation.

2—That the relation of accident prevention to plant management is determined by (a) the liability of the employer as defined in compensation laws, (b) the cost of accidents in money and permanent disability and their effect on the competitive position of the company's products.

3—That supervisors and workmen should be required to view accident prevention as an obligation accompanying their employment, as important as any other duty.

4—That the extent to which accident prevention can function in any plant is dependent upon the management's desire for sincere and continuous effort in its behalf, based upon a deep-seated conviction that accident prevention pays.

The plant in which this program was inaugurated covers 120 acres, comprising two blast furnaces, with a monthly consumption of over 60,000 tons of ore, 30,000 tons of coke and 15,000 tons of limestone, producing approximately 30,000 tons of pig iron. Four open hearth furnaces produce about 14,000 tons of steel ingots per month, which in turn are converted into blooms, billets and rods in rolling mills on the premises. The rods are drawn cold into various grades of wire, either on the premises or in the New England mills of the company, part of the wire being fabricated into nails, springs and electrically welded fabric for concrete reinforcement.

These operations are supplemented by an industrial railroad operating nine locomotives, three locomotive cranes, numerous yard cranes and hoists, ponderous ore-handling machinery, pig-casting cranes, a briquetting plant and facilities for handling, transfer and repair of all materials and plant equipment. There are 1,200 employees covering a wide variety of nationalities in many stages of Americanization.

In 1920 this plant averaged more than one lost-time accident per calendar day, or over 17 per 100 employees. In 1921 the ratio was 11.3 per 100 employees; in 1922, 10.6; in 1923, a little over 8; in 1924, 2.9; while in 1925 a less favorable frequency produced a ratio of 4.1 lost-time accidents per 100 employees. In these six years accidents resulting fatally have averaged two per calendar year.

To any one confronted with physical and similar operating conditions, I would recommend first the formulation of a flexible program for accident prevention, after an intensive study of individual shop, mill, furnace, railroad and yard operations. It would be unwise to incorporate any features which would be unnecessarily disturbing to operating conditions, or to allow the program to conflict with existing authority. It must also be applicable to shifting groups of workmen, who work in the early daytime this week, in the afternoon and evening next week, and in the late night and early morning the following week. It has been found impracticable to construct a program for such operation in strict conformity with recommendations of the state rating boards, but rating boards are now giving greater importance to local governing conditions and will accept and give credit for programs producing satisfactory results.

An effective program will, of course, give early attention to the physical safeguarding of the premises, machines and equipment, and the proper maintenance of such safeguards. Wherever possible, responsibility for this feature should be lodged with the mechanical or engineering department, and the safety engineer should as far as possible act in an advisory capacity.

Physical Qualifications.

The next logical step is human safeguarding, and this begins in the selection of the proper man for the job. Physical examination is a valuable introduction to the newcomer, and its benefits may be divided between employer and employee. In an industry classed as hazardous it is a necessity and a humane act towards the new employee. It is not desirable, however, to set standards of acceptance too high, for men are not machines and their fitness can not be reckoned wholly from the findings of a physical examiner, however expert he may be. Temperament, intelligence, adaptability, skill and general disposition towards the work are important factors.

Protective apparel and appliances play an important part in human safeguarding, but the subjects of goggles, helmets, respirators, gas masks, gloves, hand-leathers, leggings, aprons, shoes and the like comprise too large a topic for elaboration within brief limits. Emphasis should be placed however, upon the value of proper protective apparel and appliances, with due attention to both protection and comfort.

Instruction and Supervision.

Another point of vital importance is provision for proper instruction of the new employee, with close observation during his first few days of routine and kindly guidance through the period required for him to become familiar with working localities, machines and plant practice.

Practice regulations should engage the attention of the safety engineer. By this I mean general orders backed by the authority of the management, prescribing clear-cut methods of doing certain work in the face of known hazards. These regulations will be formulated only after exhaustive study of the hazards and the requirements of the manufacturing process. The authority back of such regulations should be unquestioned and no regulation should be prescribed that can not be rigidly enforced.

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*Read before the Industrial Relations Association and reprinted from National Safety News, June, 1926.

†Director of Safety, Wickwire Spencer Steel Company, Buffalo, N. Y.

The selection of assistants on the accident prevention job should next engage the attention of the safety engineer, on the theory that one man alone cannot be expected to accomplish much. A general committee (headed by the operating manager or his assistant) with two or three department managers and the plant engineer as members, and the safety engineer as the working force and secretary, make a very valuable board for the guidance of the program, for the investigation of major accidents, the consideration of statistical information and the promulgation of important regulations. This committee should be clothed with considerable authority and should administer disciplinary measures with the full sanction of the management.

Departmental committees, consisting of the department head as chairman, and department supervisors, have been valuable factors in bringing into department practice the orders of the general committee, in accomplishing a detailed study of department hazards and in guiding safety practices among the workmen. Committees of workmen are of real value in plant inspection and suggestions, providing their work is intelligently guided and their activities directed along definite lines. The casual, unguided inspection of a plant is of doubtful value, but an inspection carefully laid out and directed towards specific features of the property and operation may be of inestimable usefulness to a general committee, and also serve to educate members of the committee. It is usually desired that workmen's committees be small, that membership be rotated, so that many empolyees shall serve, and, most important of all, that they be made to work hard.

When Prevention Fails.

Our general committee meets at least once a month and special meetings are called for the investigation of major accidents. Twelve departmental committees also hold one meeting per month. Workmen's committees make a monthly inspection and report. In addition, each of our 88 foremen submits two reports per month, which are known as "reports of precaution" and are a record of precautionary instruction given to the men under their supervision. These reports give the names of the men addressed and most of them involve meetings of the various groups.

But the foregoing preparations will not prevent all accidents, so our next concern is the care of the injured employee. First aid rooms, dispensaries and hospital facilities should be adequate. The selection of physicians, surgeons and specialists will depend upon the accident problem and the type of insurance policy covering the compensation risk. Due attention will be given to the rehabilitation of the seriously injured. During convalescence a close personal relationship with the injured is desirable, keeping him on the job and on the payroll whenever the physician says there is no danger.

Immediately following an accident an investigation should be made covering the facts and the mechanical and operating conditions at the time. In minor accidents this investigation may be cared for by the safety engineer, and may call for little corrective action. However, some descriptive notice to supervisors should be made, so that the injured worker may be closely observed and subsequent dressings of the wound may be made by nurse or physician as necessary.

The general committe should conduct an investigation of all major accidents. They should develop a true and complete history of the occurrence, with a clear statement of operating conditions. After due deliberation they should rule unanimously on the direct cause, the contributing cause, and determine who may have been directly or indirectly to blame This committee should record the protective measures taken since the accident and prescribe definite action to prevent a like occurrence.

It is important that the findings of the investigating committee be made known to the employees, without regard to the feelings of those subjected to criticism or discipline. It is also important that the rulings of the committee be transmitted personally to the employee who may be named as responsible for the accident.

The program above outlined is calculated to surround the plant with a protective safety atmosphere, which should be evident to a worker on his first day of employment. The maintenance of such an atmosphere in a busy industrial plant is accomplished by a continuous educational campaign.

The direction of this educational program lies with the safety engineer, and it begins with educating his superior officers and transmitting to them information gleaned from current and past experience. He will reach the general management chiefly through periodic reports; department heads and supervisiors by circular letters; and the workers by bulletins, both supplied by outside agencies and locally prepared. The workers's education will be supplemented by messages on pay envelopes, by plant signs, slogans and various other graphic safety devices.

Statistical Studies.

I would also recommend that the character, frequency and severity of accidents, their causes and distribution over departments, be made known to the entire plant, reserving only accident costs for the management.

Statistical studies of accident prevention furnish ample material for an educational campaign. In our tabulating of lost-time and reportable accidents we undertake to group them under the following heads: departments, subdivisions, supervisors, occupation, age of injured, term of employment, time of occurrence, the cause, class of injury, part of body injured, number of working days lost, amount of medical and hospital expense, class of disability (fatal, permanent total, permanent partial or temporary), compensable or not, and amount of compensation. By these studies we have been able to display on our office walls for the benefit of foremen and others graphic presentations of accident prevention data covering a period of years. Perhaps the most essential part of it is the study of causes, and the recording of these should be made with impartial judgment.

Measuring the Results.

The reason for this elaborate safety program is that manufacturing regulations are more easily established and enforced than accident prevention rules. Results measured by "products damaged in manufacture" are more impressive to the average man than results measured by "damaged personnel." But an accident, in its essence, is faulty plant practice. It indicates clearly that some worker or group of workers, some supervisor or group of supervisors, has fallen down on the job.

The most effective method I have found to drive home the necessity of safe practice is to measure the supervisor by the accident record, to gauge his fitness for promotion, if possible, by the accidents suffered by his men.

The result to be expected in a program modeled along these lines and pursued diligently is an early reduction in frequency of accidents. This may at first be accompanied by an increase in average severity, because the minor accidents will be more easily prevented. A continuance of effort, however will surely show a reduction in total severity, and any long continued reduction in frequency will ultimately bring about a greatly reduced severity.

Let me caution you, however, never to be misled by a favorable, or unfavorable experience, if of short duration and never to feel that you have the situation under control. The future will no doubt bring new laws and greater burdens on industry, but happily these will be accompanied by better standards of fitness, as the result of educational work in schools and colleges. In the next decade, when workmen undertake industrial jobs, they will be made to recognize at the outset that every factor of authority at the plant has accepted standards of safe practice as necessary to their continuance on the job. Leaders in industry will be judged by their ability to safeguard men, and workmen will be more intelligently placed in occupations suited to their mental and physical equipment, where they will be able to co-operate to the fullest extent in those high standards of plant safety which manufacturers will have made an integral part of each industry.

Canadian Metal Industry Review

THE metal-working trade throughout Canada is well employed at present. Industrial operations are continuing at such a rate that there is a steady call for material. Seasonal business, much of which has been placed because of improved conditions in Western Canada, has aided steel mills to continue active. Rail-rolling is being done in many of the big plants and it is confidently believed that further business from the railroads will be shortly forthcoming.

The Algoma Steel Corporation reports a recent order from the Canadian Pacific Railway, which will keep the rail plant working at capacity until September at least. This company also reports a marked increase in the demand for all steels from the automotive industry. The improvement in automobile production throughout the Dominion is reflected in imports of auto parts from the United States. The purchases for the twelve-month period ending April 31 were valued at $23,077,000 as compared with $14,374,000 in the 1925 period. The most recent report on auto production in Canada shows that for the first quarter of the year the cumulative production showed an advance of 45 per cent over the total for the same period in 1925.

Some reduction in operation of foundries is noted, particularly in Quebec, but the average rate has not fallen below 50 per cent of capacity.

Although the Dominion market takes its cue from Pittsburgh, being forced to do so by competitive conditions, cases such as that in the pig iron market, where the Canadian price is now lower than the American price, plus freight and duty, continue to boost the amount of business left in Canda.

Much interest among those directly interested in the welfare of the Canadian metal-working industry is centered in the hearing which opened at Ottawa recently before the Tariff Advisory Board, of the case of the steel industry, as embodied in applications by the British Empire Steel Corporation. The hearing, it is expected, will develop into a general inquiry into the steel industry in Canada, and will continue over a period of several months. At the preliminary hearing the Algoma Steel Company took the stand that the Canadian automobile industry was already adequately protected under the existing tariff. The company argued that consequently the "drawback" of 99 per cent enjoyed by the automobile manufacturers on several articles of steel was unjustified.

The representatives of the British Empire Steel Corporation argued that it was not suggested that there should be any departure from the principles of the existing tariff, but that consideration should be given to the fact that, owing to the greatly increased cost of market value of the materials subject to specific duties, the ad valorem effect of these duties had greatly decreased. Today these specific duties did not represent the same value that they did when they were imposed.

In a nutshell, the safeguard asked by the steel industry is adequate protection by means of customs duties, particularly in regard to imports from countries whose labor is cheap and whose currencies have depreciated.

Roy Wolvin, president of the British Empire Steel Corporation, made the following point: "The present duties applying on pig iron and steel products imported from countries whose currency is depreciated allow the importation of these products at a price which is much less in many cases than the manufacturing costs in Canada. This condition for some years has been destroying the steel industry of Nova Scotia, and requires immediate adjustment."

Experimental Furnace for Study of Refractories

There are numerous problems concerning the service conditions of open-hearth refractories on which it is difficult to get data from commercial furnaces. The Bureau of Mines plans to erect a small experimental furnace of 600 or 800 pounds capacity for the purpose of collecting data on problems similar to the following: The rate of saturation of roof brick with slag; the effect of rate of heating upon roof brick structure; the effect of insulation upon refractories, and the abrasion of port ends as affected by design and by gas velocities.

Heat-Treatment Data on Steel Castings*

A Study on Heat Treating Practice for Quality Steel Castings Summarized—Normalizing and Drawing Treatment Superior to Annealing or Spheroidizing

By ALBERT E. WHITE†

STEEL castings are important in many major engineering operations. As connecting links between the boiler and the turbines in the large generating stations of the present day they perform one of their most outstanding functions. Castings for this service must be sound and possess high strength combined with good ductility. The three essentials necessary for the procurement of these properties are:

(a)—Suitable composition
(b)—Correct conditions surrounding the casting of the metals
(c)—Proper heat treatment.

The last is the one with which this paper will mainly deal.

Chemical Composition.

For most steel-casting purposes straight carbon-steel castings are adequate. Alloy-steel castings may be used if properties superior to those obtainable in straight carbon-steel castings are desired. The analysis limits for straight carbon-steel castings should be as follows:

Carbon, any 10-point range desired between 0.15 and 0.50 per cent
Manganese, 0.50 to 1.00 per cent
Silicon, above 0.20 per cent
Sulphur, not above 0.05 per cent
Phosphorus, not above 0.05 per cent.

Objections may be raised against a 10-point carbon range for steel castings. Properly operated plants should find no difficulty in keeping within 10 points. Scientific heat treatment incidental to the general manufacturing operation requires a limitation of the carbon to a 10-point range if best results are to be obtained. The limitations for manganese are not so vital. Enough must be present to deoxidize the steel properly and to convert all of the ferrous sulphide into manganese sulphide. If the usual methods of heat treatment were employed, too much manganese would result in the production of a steel which would have too little ductility.

Steel castings should always have their silicon content above 0.20 per cent. If less, the steel would without doubt be wild when poured. If so, the castings would be full of blowholes and other imperfections. Sulphur and phosphorus should both be low. These elements are detrimental in the extreme in steel castings, and every effort should be made to keep them at a minimum.

Conditions Surrounding Casting.

Chapters might be written with regard to the correct conditions surrounding the casting of the metal. Some of the most outstanding of these factors are:

a—The temperature of the metal during the pouring
b—The rate of cooling:
  1—From the liquid to the solid state
  2—From the solidification temperature to atmospheric temperature
c—The methods of gating
d—The size, number, and distribution of the risers
e—The size of the casting
f—The design of the casting
g—The kind of mold.

Heat Treatment.

This paper is mainly written, however, to discuss the influence of heat treatment on the physical characteristics of steel castings. For that reason the above items will not be developed. They are, though, of paramount importance. In fact quality steel castings cannot be produced without due and proper regard for each and every one of the above items.

Heat treatment may consist of:

a—The ordinary furnace anneal
b—An air quench and a draw
c—A spheroidizing anneal, or
d—An oil or water quench and a draw.

Other treatments or modifications of the above treatment might be employed; if so, they would be the exception and not the rule. As a matter of fact, the ordinary furnace anneal is the one usually employed, though, as will be shown later, it is not the treatment which gives the best combination of strength and ductility for power-plant castings. Of the four treatments mentioned, the oil or water quench followed by a draw has not been considered. This treatment is not applicable for castings of large size. Neither is it applicable for castings of intricate shape.

Careful studies were made of:

a—The ordinary furnace anneal
b—An air quench followed by a draw
c—A spheroidizing anneal.

These studies were made on both dendritic and non-dendiritc steels for the purpose of ascertaining the effects of these treatments on these two types of steels.

In Table 1 are recorded the results of laboratory tests on dendritic and non-dendritic steels in the untreated, annealed, normalized and drawn, and spheroidized condition. Figs. 1 and 2 were drawn from the values given in Table 1. They show the effects of the different heat treatments on the tensile strength, yield point, reduction of area, and percentage of elongation. Fig. 3 shows the effect of different laboratory heat treatments on the impact value of steel castings.

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*Contributed by the Power Division and presented at the annual meeting, New York, November 30 to December 4, 1925, of the American Society of Mechanical Engineers. Slightly abridged.

†Professor of Metallurgical Engineering and Director of Department of Engineering Research, University of Michigan. Member A. S. M. E.

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Results of Laboratory Tests.

These tests demonstrated the following:

a—The presence of dendrites makes but little difference from a tensile and impact-test standpoint. This statement, however, does not imply an endorsement of dendrite-manifesting steels, for such steels are, for a number of reasons, undesirable.

b—The tensile strength, yield point, reduction of area, percentage of elongation, and impact properties are improved by any one of the three heat treatments.

c—The spheroidizing treatment is superior to the annealing and normalizing treatments insofar as the reduction of area and percentage of elongation characteristics are concerned.

d—The spheroidizing treatment is vastly inferior to the annealing and normalizing treatments when measured by the impact test.

e—The normalizing treatment gives impact results approximately 100 per cent greater than any of the other treatments.

f—Finally, by far the best all-around properties are obtained by the normalizing and drawing operation when the criterion is high strength, fair ductility, and maximum resistance to impact.

Plant Tests.

These laboratory tests were augmented by plant tests on commercial runs of large power-plant castings. The results are recorded in Table 2 and in Figs. 4, 5, 6 and 7. The tests were divided into two groups on the basis of carbon content; one group consisting of castings with from 0.30 to 0.35 per cent carbon and the other group with from 0.36 to 0.41 per cent carbon. These tests record values only after an annealing or a normalizing and drawing operation. They confirm beyond any question of a doubt, however, that normalized and drawn castings intended for power-plant purposes have properties superior to those produced by the standard anneal.

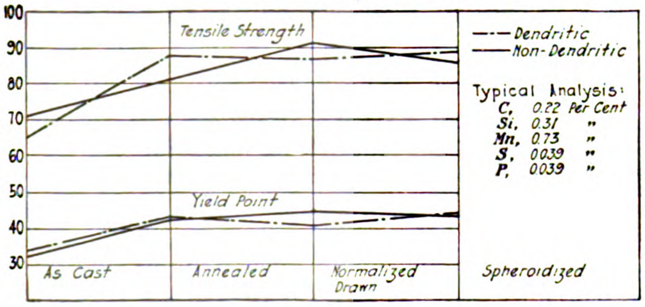

FIG. 1—Relation between the tensile strength coupled with the yield point and the heat treatment of cast steel.

It is strongly recommended, therefore, that all large castings for power-plant purposes be heat-treated by the normalizing and drawing method. Briefly, this method consists in evenly heating the castings to between 1750 and 1800 deg. F., and holding them within this temperature range until uniformly heated. They should then be cooled to 100 deg. F., or below, in still air. The castings should then be uniformly heated to 1200 deg. F., after which treatment they may be cooled as desired.

With clean, sound castings of suitable composition thus treated, power plants and other users of quality steel castings would get the highest obtainable present-day value in steel castings.

Discussion.

L. W. Spring* wrote comparing the method of heat treatment suggested by the author with the older "dead anneal" method, stating that the former was a somewhat better method, especially as to yield point, reduction of area and impact values. He also commented on the improved grain size and arrangement, and stated that he foresaw little disadvantage, at least for fairly plain and sufficiently heavy castings. Unless the castings were thin-walled and complicated or delicate in alignment, he felt that the 1200 deg. F. "draw" should relieve stresses and insure retention of shape and contour.

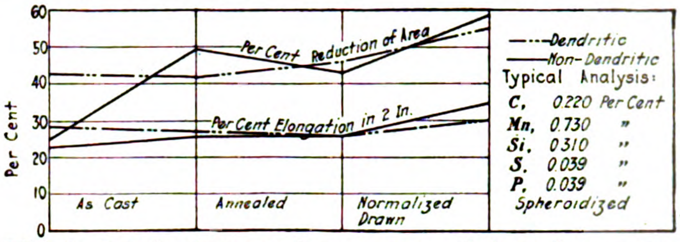

FIG. 2—Relation between the percentage of elongation coupled with the percentage of reduction of area and the heat treatment of cast steel.

In a written discussion of the paper, V. T. Malcolm† stressed the importance of high-pressure fittings conforming to rigid specifications and being covered by strong guarantees. He said it was very important, in order that the manufacturer might stand back of the guarantees, that he be thoroughly familiar with the manufacturing processes, and that theory and practice should be so co-ordinated that a high state of efficiency might be developed.

In commenting on the "normalize and draw" treatment, also the detrimental effect of the dendritic structure, Mr. Malcolm said that his company had adopted this treatment after investigation and had found it satisfactory. The dendritic structure, he said, was one which they had found should never exist in quality castings, it being possible to readily guard against it if proper precautions were taken. Its existence he attributed to the use of sand molds into which metal at incorrect temperatures was poured, the temperature being held within the granulating stage too long after solidification of the metal. This condition would result in a coarse-grained structure, he said, under which crystalline growth occurred by linear disposition, producing the so-called dendritic structure, any

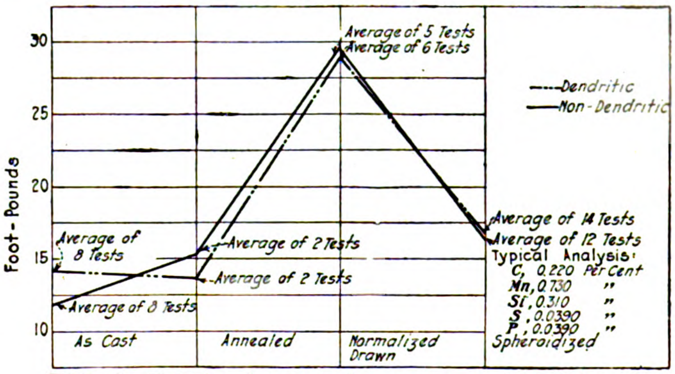

FIG. 3—Relation between impact strength and heat treatment of cast steel.

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†Metallurgical Engineer, The Chapman Valve Manufacturing Company, Indian Orchard, Mass.

impurities contained in the steel being rejected to the grain boundaries, where they could not be eliminated by heat treatment.

The production of clean, sound steel Mr. Malcolm considered the first requisite in the manufacture of high-grade castings, placing the proper treatment of the castings as the second requisite and of equal importance. High-grade steel castings poorly treated might be inferior to those made of low-grade steel but properly treated. He emphasized the importance of keeping the chemical analysis of the steel within certain limits, in order that the treatment cycle, once set, might be maintained constantly. The correct temperatures for pouring, thorough oxidation, etc., were considered of great importance, owing to the effect on grain structure and the heat-treatment operations.

Mr. Malcolm summed up the purpose of heat treatment as follows: To increase softness and ductility; to secure a desirable combination of strength and elastic limit with fair ductility and resistance to shock; to eliminate existing coarseness of grain and to impart to the steel a fine, dense structure, insuring toughness; and to relieve internal strains that might be caused by uneven contraction of castings in the mold.

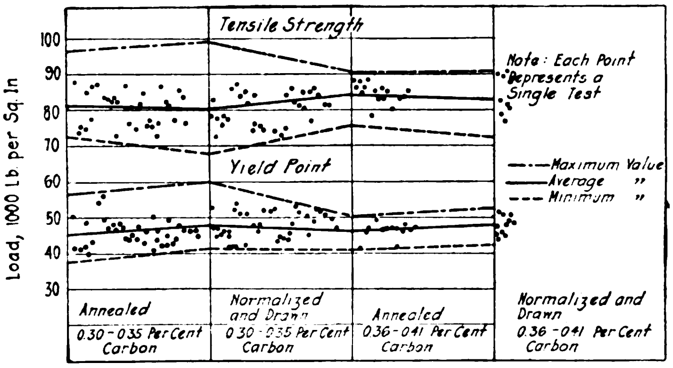


FIG. 4—Results of commercial tests showing the relation between the tensile strength coupled with the yield point and the heat treatment of cast steel.

In treating steel, he said, the first point to be considered was the temperature required to break down the coarse structure. The second point was the length of time to keep the casting at the required temperature. Complete saturation of the casting was most essential, and prolonged soaking preferable to incomplete saturation. The third point of importance was the cooling from soaking temperature, rapid cooling being preferable, followed by drawing to produce the physical characteristics required. Slow cooling in the furnace from the soaking temperature had been found unsatisfactory.

The method of charging the castings into the furnace and the manner of withdrawing them also would have a great bearing on the uniformity of the product. Steel castings properly heat-treated would possess physical characteristics comparable with heat-treated forged steel.

R. A. Bull, as a representative of the American Foundrymen's Association on the Joint Committee on the Investigation of the Effect of Phosphorus and Sulphur on Steel, discussed in writing results obtained from co-operative research. In writing of the work of the committee he said that there had been nothing uncovered on the influence of phosphorus, but in the temporary absence of reliable data regarding the product of the steel foundry, it seemed reasonable to assume that the effects of sulphur in finished steel castings under test or service conditions would be unlike those in rolled steel. He felt that it was clear to every one who had examined the data collected by the committee that there was no scientific basis for an unqualified statement that sulphur was decidedly injurious to steel castings and that every effort should be made to keep that element as low as possible.

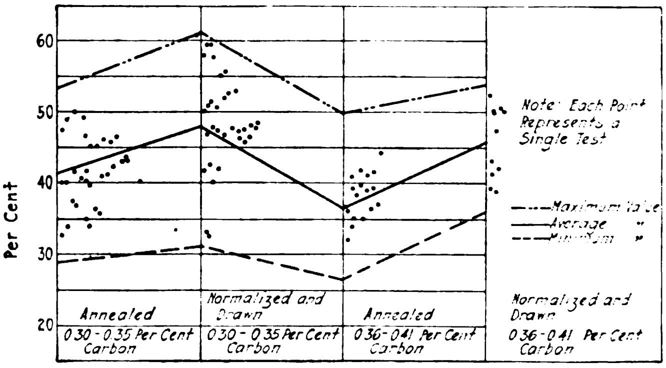


FIG. 5—Results of commercial tests showing the relation between the percentage of reduction of area and the heat treatment of cast steel.

Mr. Bull further commented on the unbiased nature of the individual opinions of members of the committee, and said that he felt that when its report was completed it would be found to have been prepared to give engineers facts rather than suspicions upon which to base their practices. He expressed the hope that engineers would refrain from forming conclusions which, like those of the author on sulphur, were not justified by anything ascertained by the committee.

Referring to the author's establishment of 0.50 per cent and 1.00 per cent, respectively, as maximum limits for carbon and manganese for what he termed straight-carbon-steel castings, as distinguished from alloy-steel castings, Mr. Hall said that metallurgists had found difficulty in distinguishing between some alloy or special steels and carbon steel. He said that considerable steel for casting was purposely made higher in percentage of carbon or manganese than indicated in the paper, and that many did not class such steels as alloy steels, which were represented by steels containing nickel, chromium, etc.

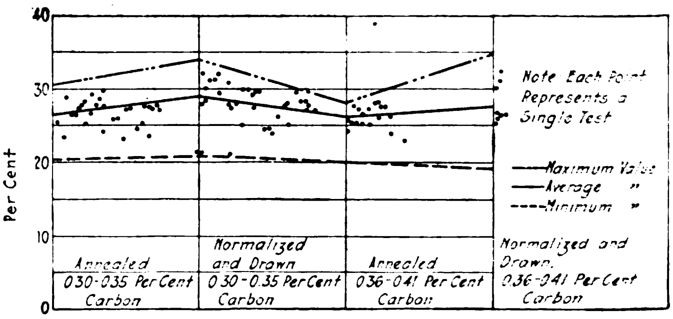
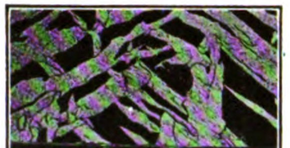
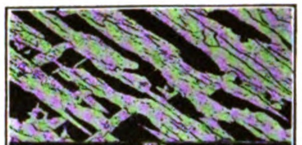
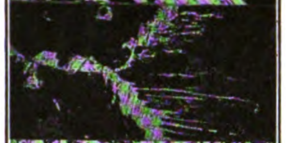
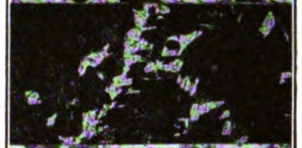
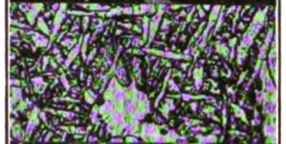
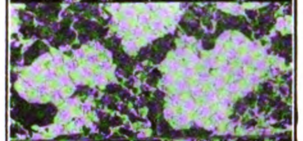
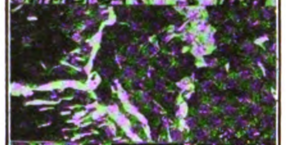
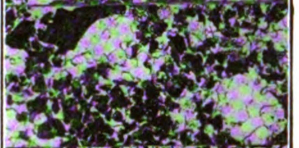
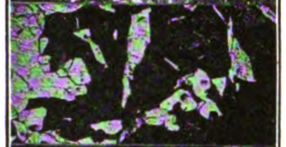
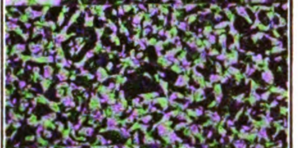
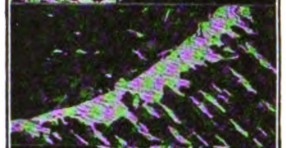
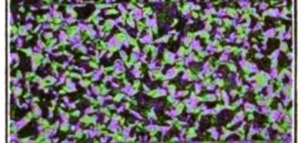
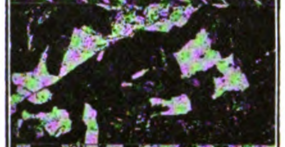
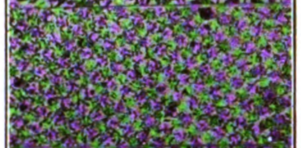
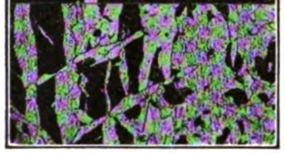
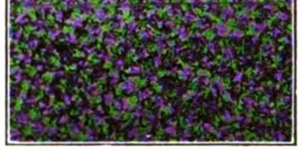


FIG. 6—Results of commercial tests showing the relation between the percentage of elongation and the heat treatment of cast steel.

In closing, the author said that Mr. Bull's comments on the nature of the paper's reference to sulphur would lead one to believe that the upper limit on sulphur should either be removed or else materially

TABLE 1 SHOWING THE RELATION BETWEEN TYPE OF STRUCTURE, HEAT TREATMENT, AND PHYSICAL PROPERTIES FOR MEDIUM-CARBON CAST STEEL

Bar No.	Initial condition	Micro-structure before treatment	Heat treatment	Micro-structure after treatment	Tensile strength, lb. per sq. in.	Yield point, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of area, per cent	Impact strength, ft-lb.
13	Dendritic.		(1) No treatment.		65,500	34,100	28.13	41.80	14.25 Bar No. 15
14	Non-dendritic.		(1) No treatment.		71,300	32,600	23.28	25.61	11.80 Bar No. 16
1	Dendritic.		(2) Heated at 1760 deg. fahr. for 7 hr. Furnace-cooled.		88,000	43,700	27.00	41.60	13.50 Bar No. 3
2	Non-dendritic.		(2) Heated at 1760 deg. fahr. for 7 hr. Furnace-cooled.		81,200	42,800	26.00	49.00	15.25 Bar No. 4
5	Dendritic.		(3) Heated at 1760 deg. fahr. for 7 hr. Air-cooled. Heated at 1100 deg. fahr. for 6 hr. Air-cooled.		86,650	41,000	26.00	46.26	29.00 Bar No. 7
6	Non-dendritic.		(3) Heated at 1760 deg. fahr. for 7 hr. Air-cooled. Heated at 1100 deg. fahr. for 6 hr. Air-cooled.		91,350	44,700	26.00	43.55	30.50 Bar No. 8
9	Dendritic.		(4) Heated at 1760 deg. fahr. for 7 hr. Air-cooled. Heated at 1275 deg. fahr. for 30 hr. Air-cooled.		78,600	44,600	30.50	56.50	16.55 Bar No. 11
10	Non-dendritic.		(4) Heated at 1760 deg. fahr. for 7 hr. Air-cooled. Heated at 1275 deg. fahr. for 30 hr. Air-cooled.		76,000	43,800	34.00	58.57	15.20 Bar No. 12

(1) As cast. (2) Annealed. (3) Normalized and drawn. (4) Spheroidized.

raised. He appreciated that there had been a consistent effort on the part of certain steel manufacturers, much if not all of which had been in good faith, to raise the rejection limit of sulphur. Some interesting data had been presented by the Joint Committee on the Investigation of the Effect of Phosphorus and Sulphur on Steel. Though the information now available suggested the possibilty of raising the rejection limit, many engineers were nevertheless loath to approve such a course, feeling that the data were not sufficiently comprehensive or sufficiently well seasoned to warrant such a step.

TABLE 2

AVERAGE RESULTS OF COMMERCIAL TESTS FOR STEEL CASTINGS BY THE CRANE COMPANY

Heat treatment	Carbon content, per cent	Tensile strength, lb. per sq. in.	Yield point, lb. per sq.in.	Elongation, in 2 in., %	Reduction of area, %	Izod impact value, ft.-lb.
Annealed ..	0.30-0.35	81,141	45,307	26.37	41.30	22.20
Annealed ..	0.36-0.41	84,800	46,391	24.06	36.07	19.50
Normalized and drawn	0.30-0.35	80,016	48,100	28.88	47.72	24.94
	0.36-0.41	83,000	48,000	27.50	46.00	24.00

The author was not aware that such representative bodies as the American Society for Testing Materials or the Society of Automotive Engineers or other organizations interested in specifications had made any material, if any, modification of their sulphur limits in specifications. Also sulphur and phosphorus had been the two elements on which the two steel-castings committee of the American Society for Testing Materials had been in quite general agreement as to a desirability for limitation. No one, to his knowledge, believed sulphur added desirable qualities to steel beyond which any emphasis was placed in steel castings.

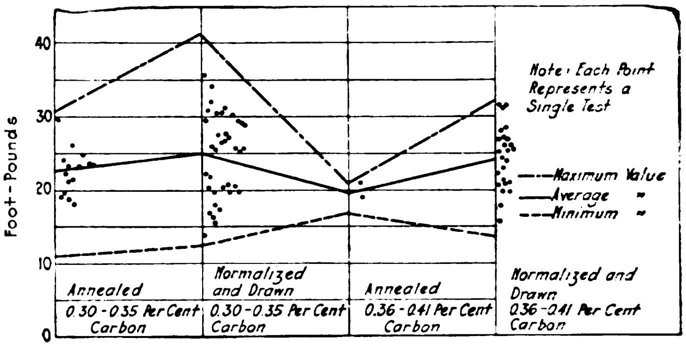


FIG. 7—Results of commercial tests showing the relation between the impact strength and the heat treatment of cast steel.

He granted that this might be libeling sulphur. It was not beyond possibility that sulphur might have been cavorting in bad company, but until there was further information on the subject than was at present available, consumers would not be justified in changing their views with respect to its detrimental characteristics.

The Mysore Iron Works

This Article Comments on the Financial Position and Administration of the Mysore Iron Works—A Description of the Plant Appeared in a Previous Issue

By A. P. SOM*

FROM time to time comments have been made both in the press and on the floor of the Mysore Legislative Council, regarding the financial position and administration of the Mysore Iron Works. The Board of Management have not been publishing any particulars for the information of the public until very recently, because the work is a commercial concern and it is not usual in such concerns to discuss in public the details of profit and loss, output and overhead, etc., though the Government of Mysore were being kept informed by means of periodical reports and notes. In order to remove growing misapprehensions, the Board have now issued a brief statement outlining the origin, present position and future prospects of the industry.

The undertaking has passed through thee stages, viz., (1) inception, (2) construction and (3) operation. The preliminary investigations in connection with this project were begun in 1915-1916. After a thorough investigation by experts both in and outside the State, the scheme was sanctioned by the Government of His Highness, the Maharajah of Mysore, in 1917-1918. The first order for machinery was also placed in the same year with the consent of all the members of Government concerned and an agreement appointing the Tata Iron & Steel Company, Ltd., as Managing Agents was formally ratified in May, 1918. Sir M. Visvesvaraya who was Prime Minister at the time the scheme was sanctioned, retired from office in December 1918, and the actual expenditure on the works up to June 30, 1919, i. e., up to six months after his retirement was only Rs. 8.45 lakhs.

The construction was commenced in 1918, with Messrs. Perin and Marshall of New York as Consulting Engineers. The tramways, forest and mining sections of the works were under the direct supervision of the Mysore Government. The works were expected to be ready for operation by the end of 1919, but for various reasons briefly referred to below the construction stage was prolonged for nearly 5 years or till January 1923 when the blast furnace was blown in and the operation began for the first time.

When the construction was nearing completion, several officers including a member of the firm of Messrs. Perin and Marshall were for closing down the works but Mr. Perin himself was opposed to such a proposal. At the request of His Highness' Government, Mr. Perin came over to Mysore from New York and started the operation. When he left in March 1923, the management of the works was transferred to a new Board and at the request of His Highness' Government, Sir M. Visvesvaraya joined this Board as

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*Jamshedpur, India.

Chairman and he was vested with special powers and responsibilities. From that time up to the present, the management has remained in the hands of this new board, which besides, the chairman, is now composed of Sir K. P. Puttanna Chetty, Haji Sir Ismail Sait, and Mr. J. D. Ghandy of The Tata Iron & Steel Company, Ltd. In May 1924, the agreement between the Government of Mysore and The Tata Iron & Steel Company, Ltd., was by mutual consent cancelled and the latter ceased to be the Managing Agents of the concern.

During the construction period the estimated capital cost of the works went up from Rs 94 lakhs to Rs 211 lakhs. Large purchases during a period of high costs, delay in the completion of the plant and absence of close supervision by a central administrative and engineering agency led to a very considerable excess over the original estimates. Change of design without proper sanction was also partly responsible for the large excess. The works as originally designed could be installed today within the limits of that estimate. The actual outlay by the time the new board took charge in April 1923 had risen to about Rs. 167 lakhs. The over-capitalization took place during the construction period.

Over-capitalization is the main defect of the works at present. In a case of this nature, it is usual to write down the capital in order to cancel the excess expenditure not represented by available assets. This was done recently in the case of two out of the three other undertakings of a similar character connected with the manufacture of iron and steel in India. It is a question for consideration whether a similar procedure should not in the larger interests of the works be adopted in this case also.

The operation of the works has been gradually improved and stabilized during the past three years. Since October 1925, a special attempt has been made to cut down costs and reorganize the works. The output of pig iron, which was about 30 tons per day during the first half year of operation, has now risen to about 57 tons. Local Indian staff has been trained to do the work. The yearly manufacturing cost has been brought down from about Rs 19 lakhs estimated by Mr. S. M. Marshall in 1922 to Rs 13.5 lakhs. For the past three months in spite of the prices having reached the lowest level known, the receipt or the estimated value of the products manufactured practically balance the expenditure. Certain subsidiary industries have been started, such as a pipe foundry and an alcohol refining plant which are expected to be completed by July 1 next and thereafter to yield some additional revenue on their own account.

Various misgivings entertained at the time the scheme was sanctioned, are now found to be without foundation. It was thought that the wood supply would fail. Not only has it not failed but a smaller forest area than originally contemplated is found to be sufficient to meet the needs of the plant. It was feared that the forests would be denuded. In actual practice, only waste material for which there is no other use, is being removed. The local forest department are able to assure the public that the forest conservation requirements are fully met. If anything, the exploitation is expected to improve the yield of timber in future years. The rates allowed in the original estimates for the collection of wood were at one time considered too low, but in operation the costs have been even lower. There were apprehensions in some quarters that the products might not sell freely. But experience shows that the quality of Mysore products is appreciated wherever it is used, whether in India or in foreign countries, particularly charcoal iron which has been pronounced to be a high grade iron.

The loss in actual operation in three years has been Rs 8.70 lakhs and that due to the writing down of the stock on account of market prices, Rs 5.16 lakhs or Rs. 13.86 lakhs in all ($450,000 nearly). Much of the loss was mainly due to the phenomenal fall in the price of iron, a special disadvantage from which the Mysore works have suffered. The operation was started at a time when a trade depression of unprecedented intensity commenced. The price of pig iron which was Rs 100 per ton in 1923 has been going down steadily and the decline has continued to this day. It is now Rs 45 to Rs 50 per ton at the works. If the prices which obtained at the time when the present board took charge in April 1923 could be secured now, the works would be laying by a sum of about Rs 5 lakhs per annum after meeting depreciation charges. During 1925 the iron and steel industry passed through the worst depression known for half a century. This has affected the other iron industries in India and indeed all over the world. Some have been shut down temporarily. Many continue to operate because the Governments concerned are supporting them by granting subsidies, protective duties, etc. The total loss of Rs 13.86 lakhs has been treated as a subsidy given by Government, similar to subsidies or bonuses granted in the Dominions and in foreign countries.

If the prices improve or the exchange become more favorable than has been the case in the past three years, or if the subsidiary industries begin to pay, the profits from the Mysore works will be appreciably increased. With the improvement of the receipts, a reserve could be maintained for the depreciation charges. When this stage arrives, the permanency of the works will have been ensured.

One point which is not remembered in the discussions is that engineering works of this magnitude require time to develop. They are not expected to pay the full dividend usually for 8 or 10 years, after they are started and many do not pay any dividend for a longer time. The experience of the three other undertakings in India has been the same. In the case of the Mysore undertaking, the time to judge will be after it has had sufficient time to train the requisite staff, stabilize its operations and build up its own market, and when the normal market conditions come to prevail.

As stated before, the works in other respects are shaping well. The present position cannot be said to be unsatisfactory since the industry is able to balance receipts and expenditures at a time of great world trade depression. The future looks more hopeful, because till now the prices have been falling and they have reached a stage when no further fall is held to be likely. Hitherto the value of stock had to be written down with declining prices, but this may not be necessary in future. A market for our products has been developed. The entire output of pig iron produced during the last half year has been sold. The management is confident of doing the same in the current half year also. If things do not go very wrong, the board are hopeful that they will be able to carry on the works in future without further financial assistaance from Government.

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Convertors and Motor Generator Sets*

The Author Has Prepared the Following Article to Furnish an Analysis of the Inherent Characteristics of Synchronous Convertors and Motor Generator Sets

By W. B. SNYDER†

WHERE direct-current power is needed for industrial requirements and the supply is a.c., both the synchronous converter and the synchronous motor-generator set are well adapted for the purpose, since each possesses large momentary overload capacity, is thoroughly reliable, and is easily controlled either by hand or automatic means. Obviously, however, neither of these two types of machines is more serviceable than the other under all conditions, so there frequently arises the need for comparative information as to the inherent advantages of each type in order that the one which will be better adapted to a certain installation may be selected. The factors involved in the choice are:

First Cost and Efficiency
Power-factor
Power Contract
Power Supply
Direct-current Load.

First Cost and Efficiency.

The first cost of a synchronous converter with its accessory equipment is about 10 per cent less than the first cost of a motor-generator set with its corresponding equipment; and the efficiency of the synchronous converter is from 5 to 7 per cent higher than that of the motor-generator. Other things being equal, these two factors alone are of such great importance that the choice would be in favor of the synchronous converter. This may be reversed, however, by a consideration of the other factors.

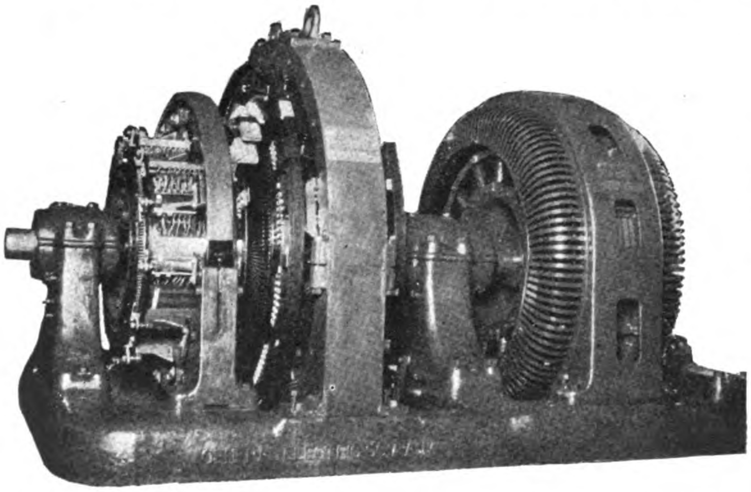

FIG. 1—A typical motor-generator set; the generator rated 1500 kw., 514 rpm., 250 volts, and the motor rated 2100 kv-a., 514 rpm., 2300 volts.

Power-factor.

The synchronous converter, as usually designed for industrial service, operates at approximately unity power-factor over a range from full load to three-quarter load. As the load is further reduced, however, the power-factor is lowered very rapidly, being around 95 per cent lagging at one-half load, 55 per cent lagging at one-quarter load, and 20 per cent lagging at no load. The converter therefore cannot be depended upon to improve the power-factor materially, although at one-half load and above the power-factor is very good.

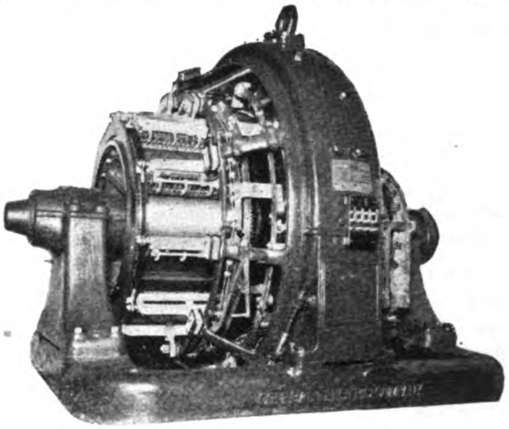

FIG. 2—A typical synchronous converter, rated 2250 kw., 300 rpm., 250 volts.

In the case of synchronous motor-generator sets, the full-load power-factor may be unity, 85 per cent leading, or 80 per cent leading, depending upon the motor used. Sets for industrial service are usually equipped with 85 per cent power-factor motors. Unlike the synchronous converter, a synchronous motor will operate at a better power-factor at light load than at full load. Thus, a motor operating at 85 per cent leading power-factor at full load will run at 55 per cent leading power-factor at one-half load, 33 per cent leading at one-quarter load, and 15 per cent at no load, provided the field excitation is unchanged. The motor-generator set thus possesses inherent characteristics which improve the power-factor of the total plant load.

Looking at the question of machine power-factor from another point of view, the synchronous converter at no load draws from the line approximately 27 per cent of its rating in lagging kilovolt-amperes, this value decreasing to approximately 12 per cent at full load; while the 85 per cent power-factor synchronous motor will deliver to the line approximately 70 per cent of its rating in leading kilovolt-amperes at no load, this value decreasing to 52½ per cent at full load.

Power Contract.

Power contracts vary considerably. Most of them have a demand charge and an energy charge, in addi-

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†Industrial Engineering Department, General Electric Company.

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tion to which some have a power-factor clause that requires the customer to pay a higher price when the average power-factor is below a stated value. Insofar as the demand and energy charges are concerned, the synchronous converter has a clear advantage of 5 to 7 per cent because of its higher overall efficiency. If the contract contains a power-factor clause, a careful determination should be made as to what the power-factor of the total load would be with the converter and with the motor-generator set. There are cases where improved power-factor will produce a saving in the power bill more than sufficient to offset the higher combined demand and energy charges of the motor-generator set, and if this factor be the ruling one it would justify the additional expenditure for the motor-generator set.

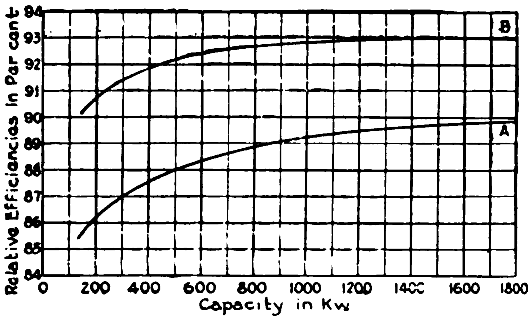

FIG. 3—Curves of efficiency. (a) Motor-generator sets. (b) Synchronous converters with transformers. The losses included are those of the converter, transformer, and a.c. bus between the converter and transformers.

Power Supply.

The ratio of the d.c. delivery voltage to the a.c. supply voltage is more or less fixed in the case of the converter, but is not in the case of the motor-generator set. A limit is thus placed on the possible variation of the d.c. voltage of the converter, by changing its field excitation, in order to overcome variations in the a.c. supply voltage. If, for example, the d.c. voltage of a synchronous converter is increased 10 per cent by changing the field setting, the heating of certain armature bars will be as much as three or four times normal. It is evident, therefore, that if the regulation of the a.c. voltage supply is beyond that permitted on the d.c. system, a synchronous converter should not be used. If, on the other hand, the variation in supply voltage is within the limits allowable for the synchronous converter this equipment should be entirely satisfactory, at least with respect to the d.c. voltage delivered.

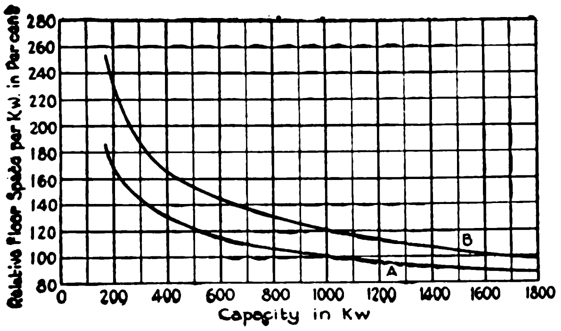

FIG. 4—Curves of floor space per kw. of capacity. (a) Motor-generator sets. (b) Synchronous converters and transformers.

Since the d.c. voltage of the synchronous motor-generator set is independent of the a.c. voltage supply, the motor-generator set is better adapted than the synchronous converter for those installations where the a.c. voltage regulation is such as to cause d.c. voltage variations beyond those allowable in the d.c. load circuits.

Direct-current Load.

If the nature of the d.c. load is such that over-compounding, frequent adjustment of voltage, or parallel operation with other motor-generator sets or engine-driven d.c. generators is required, the motor-generator set should be used. The synchronous converter may be successfully paralleled with other converters, but it is very difficult to secure successful parallel operation between converters and motor-generator sets, or engine-driven d.c. generators. This is due to the fact that every voltage disturbance on the a.c. side of the converter proportionately affects the d.c. voltage. In any case, the best practice would indicate that a synchronous converter should be chosen where the proposition involves parallel operation with a synchronous converter installation, and that a motor-generator set should be selected as an addition to a previous installation of motor-generators or engine-driven d.c. generators.

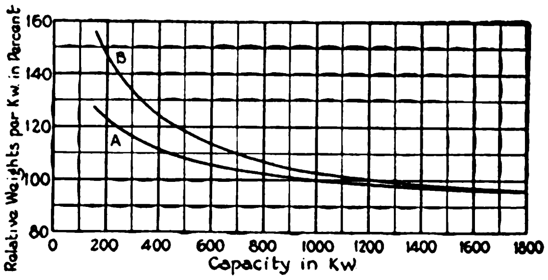

FIG. 5—Curves of weight per kw. of capacity. (a) Motor-generator sets. (b) Synchronous converters and transformers.

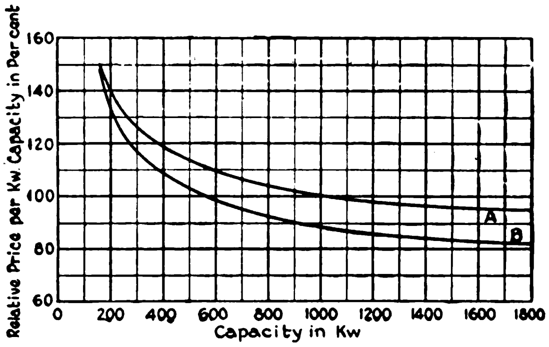

FIG. 6—Curves of price per kw. of capacity. (a) Motor-generator sets with complete switchboard. (b) Synchronous converters with transformers, complete switchboard, and a.c. bus material between converter and transformers.

Other Considerations.

The motor-generator set has a slight advantage over the synchronous converter with respect to floor space, while for light weight of individual parts, ease in lining up and replacing armatures, the advantage is with the converter.

Protective Coatings For Metals

The First of a Series of Educational Articles Dealing with Various Methods for Protecting Metal Surfaces Against Corrosion and Oxidation

By JAMES A. AUPPERLE*

PART II

THE sherardizing process was discovered by accident. Commander H. V. Simpson, of the English navy, was detailed to work out a method of case hardening armor plate for battleships that would not infringe on the Harvey patents which were being used by nearly all governments for rendering armor plate shell proof. These experiments were being tried out in the laboratory of Sherard Cowper-Cowles, of London, a noted English metallurgist. A package of Zinc dust had been forwarded Mr. Cowper Cowles to determine whether it could be used in making an electrolyte for zinc plating. In the course of their experiments they placed a piece of steel in this zinc dust in a case hardening oven and heated it up to see if it would have any hardening effect on metal. When taken out it was covered with a silvery coating of zinc and on examining under the microscope they found it had penetrated and alloyed the zinc with the body of the metal.

The first plant was established at the works of the New Castle Forge & Bolt Company, New Castle, Pa., and in July, 1908, about one-half ton of material was sherardized. Other plants were then established and by the following year the use of the process had increased to 1,223,900 lb. monthly. At the present time about 4,000,000 lb. per month of iron and steel are being treated by this method in the United States and Canada.

Theory of Sherardizing.

Sherardizing may be refined as a process of sublimation, occlusion, and adhesion, when considered in connection with the theory of ions. The process of passing directly from the solid to the gaseous state and from the gaseous direct to the solid state, in both cases, stepping over the liquid state, is called sublimation.

The theory of sublimation and the "triple point" in connection with sublimation is fully defined and described in many elements of physics. It is a very well known fact that solids sublime. This is easily shown, for example, in the evaporation of ice when it is kept below its melting point. In the case of most solid substances this process is so slow at ordinary temperature that it cannot be detected. At ordinary temperature and pressure camphor, arsenic and many less familiar substances sublime. Solid carbon dioxide will volatilize at 79 deg. C. at atmospheric pressure without passing through the liquid state. Zinc as a solid may change into vapor passing into the liquid state. For an exact definition of the physical condition of a body a knowledge of the values of all its variable properties is required. The three most important of these are temperature, pressure and volume occupied by unit mass of the substance. These are not independent of each other but are connected by a definite relation called the equation of state, which, in the simple state of perfect gases, takes the form of the gas law, which is the law of Boyle and Charles.

It is a well known fact that the common metals are extremely porous. This is visible under a high power magnifying glass, as well as readily demonstrated by certain physical experiments. Thus, if a steel wire placed in a vacuum tube and then heated to incandescence, as, for instance, by passing a current through the wire, the pressure within the tube rises materially and gas is evolved for a very considerable time, indicating that steel (and practically all other metals) contain large volumes of gases. The condition of the metal may be graphically described as resembling a sponge soaked with water.

How Precipitation of a Vapor on Metal Occurs.

When a porous solid is easily permeated by a gas and condensation on the surface of the pores of the solid takes place, it is called occlusion. An example of this can be seen in the absorption of 90 volumes of ammonia in one volume of charcoal. Spongy platinum will absorb about 250 times its own volume of oxygen. Paladium will absorb about 100 times its own volume of hydrogen and will increase one-tenth of its volume. To produce such a condensation alone would require a pressure of many thousand pounds per square inch. Nearly all metals absorb gases and, being heated, will allow them to pass through readily. An example of this is the fact that hydrogen will readily pass through heated iron.

There also appears to be an electrical condition accompanying the evolution of gases from a metal inasmuch as the evolved gases usually contain a number of free ions. This is particularly the case if the temperature of the metal is high at the time the gases are given off. Naturally, the exposed surface of the metal is the only portion which actively takes part in evolving gases, so that the larger the area of surface exposed the greater the evolution of gas, other conditions being equal.

Now it is a well known fact that all materials have a definite vapor tension, depending mainly on the nature of the material, the nature of the surrounding materials, the temperature and the pressure. It therefore follows that under all conditions all substances are surrounded by a certain amount of their own vapor. The vapor can be increased in amount by increasing the temperature and decreasing the pressure.

Sherardizing is now generally recognized as the standard finish and protection for all iron and steel parts including the threaded portions used in the manufacture of line material devices. Marked improvements in the process of manufacture have been made by the General Electric Company over that used in the early stages of the art, which insures to its customers a uniform product of highly efficient protective qualities regardless of shape or dimension of the part so treated. In this process zinc is deposited by baking upon the surface to be protected, the zinc first entering the pores of the metal forming a very close union with the metal, the coating is then built up to the desired thickness.

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*Middletown, Ohio.

Sherardizing withstands readily the Preece test of successive immersions in copper sulphate frequently specified by large users of galvanized materials, but this test does not indicate the actual desisting qualities of the zinc coating to the atmospheric condition in which it is used. A comparative test of sherardizing and galvanizing materials having the same weight of zinc deposited per square inch, and withstanding about the same number of emersions in copper sulphate, will show when subjected to a life test under service conditions that the sherardized coating will last more than twice the length of time of the galvanized coating, a result not shown by the Preece test.

Sherardizing has the additional advantage of furnishing efficient protection of threaded and other finished surfaces without materially altering their dimensions, whereas, in hot galvanizing, screw threads have to be recut and steel surface is, therefore, liable to partial exposure. It is also free from the weakening effect caused by hot galvanizing on malleable iron in certain forms, which has to some extent limited the employment of galvanizing in line material manufacture, and has often seriously impaired the integrity of castings or irregular sections.

The adoption of Sherardizing marks the most important step in the art of line material manufacture since the design of Catenary Construction.

Tin and Terne Plate.

Tin plate consists of iron or steel coated with pure tin while terne plate is iron or steel coated with an alloy of lead and tin. Some concerns manufacture an alloy coated sheet which contains tin and lead but in different proportions than usually found in terne plate.

In coating with tin and terne metal, the iron or steel sheets must first be thoroughly pickled in order to remove all scale and other foreign matter. The thoroughly cleaned sheets are first passed through a flux box containing a zinc chloride flux which prepares the surface taking the coating, and then into the pot containing the molten metal. The size of the pot varies considerably, a small pot holding 20,000 lbs. is used for tin while one holding 30,000 lbs. is used for long terne and alloy coated sheets.

The highest grade tin and terne plate is manufactured by omitting the zinc chloride flux and using palm oil instead. This is a more expensive process and is supposed to give a superior product. Tin plate is not used to as great an extent as terne plate for roofing purposes, as a heavier weight of coating is usually applied to terne or alloy coated sheets. It has been found that the terne plate holds paint much better than tin plate.

After the sheets emerge from the coating bath through the layer of oil, they are cleaned with sawdust in order to remove most of the adherent oil.

The average size of the sheets is 14 in. x 20 in. or 20 in. x 28 in. while long terne sheets can be made up to 48 in. x 144 in. The regular terne plate coating contains approximately 20 per cent tin and 80 per cent lead while the tin plate is pure tin, no lead being used on account of danger from poison, should such sheets be used for food containers. Alloy coated sheets are coated with an alloy of tin and lead in proper proportions to give the alloy the best fluidity in order to avoid irregular coating and to produce a smooth sheet. This alloy coating has a higher melting point than the regular terne plate mixture, and by solidifying sooner there is less variation of the weight of coating on the different portions of the sheet. The weight of coating on alloy coated sheets is approximately .5 ounce per sq. ft. or about one-third the weight of coating on the average galvanized sheet.

Terne and alloy coatings, on account of holding solder better than zinc coated sheets, are used in gasoline tanks on automobiles and aeroplanes where there is considerable vibration. They also possess remarkable paint holding properties.

When exposed to atmospheric conditions, the lead-tin alloy coatings exert a remarkable influence upon the durability of the metal. The sheets soon begin to rust and after one year, if they are not painted, the entire surface will be covered with a dense, closely adherent rust which sheds water and slows up the rate of corrosion to a remarkable extent. It has been found that the products of corrosion which are formed on these lead-tin alloy coated sheets add almost eight years to the life of the base metal. These products of corrosion consist of tin, lead and iron oxide and are of much finer grain than is produced on the same metal not coated.

Schoop Metal Spraying Process.

The Schoop metal spraying process makes it possible to spray articles with metallic coatings of zinc, lead, tin, brass, nickel, aluminum, bronze and monel metal. The process consists essentially of melting and atomizing any of the commonly known metals, either in wire or dust form and impacting them on any surface.

This coating is usually applied to metals such as iron and steel but may be applied to vitreous, fibrous or insulating materials.

This process uses both the pistol method where the metal is used in the form of wire and the gravitas method where the metal is used in the form of dust.

The pistol weighs about three and one-half pounds and is connected to standard acetylene and oxygen cylinders and to a supply of compressed air, consuming while in use approximately 15 cubic feet per hour of each of the gases, and 50 cubic feet per minute of air at 50 pounds pressure.

Metal wire is automatically pulled from a reel into the rear of the gear case in the pistol and fed uniformly and continuously at a rate of from 12 to 24 feet per minute from the muzzle of a short barrel to the melting zone where it is melted by a continuous reducing flame, developed from the gases, and is blown by the compressor at a velocity of about 3,000 feet a second (equal to the speed of a rifle bullet) in a very fine spray onto the surface being coated.

In the gravitas method, the metallic dust is fed by gravity and air pressure to the pistol where it is heated to a plastic state and sprayed onto the object. This type of pistol is very simple as it does not require the gear mechanism which is necessary for feeding the metallic wire into the pistol.

The resulting fog or spray of fine metallic particles into which the wire is divided takes the form of a diverging cone with a core of reducing gas in which the particles are entrained, and a surrounding sheath of air which is rapidly expanding and cooling. Any suitably prepared object placed in the path of this metallic spray is coated through impact without undue elevation of temperature. At a distance of 5 inches from the pistol, the diameter of spray is about 2 inches. The coating of the objects is accomplished by pointing the pistol at the surface to be coated at a distance of 5 inches and traversing the spray across the surface with a regular motion.

The operators' vision easily guides him in distinguishing between the coated and uncoated portions, and also between a first and second coat. A single coat is about .001 of an inch thick. Three coatings of approximately .003 of an inch total thickness of well impacted metal is claimed to be as effective as a much greater thickness. The thicker the metal, the less tough and adherent the coating.

When using aluminum, the metal spraying process gives a protective coating which resists high temperatures and is similar to calorized coatings. It is claimed that grate bars and other equipment subjected to high temperatures which have been treated with aluminum by this process will retard oxidation and scaling, and also that in the case of grate bars, clinkers will not adhere to an aluminized surface.

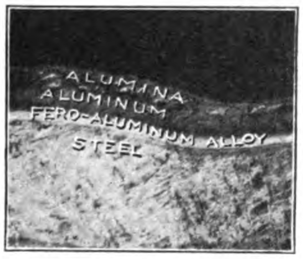

FIG. 1—Section of calorized metal.

Various metals are sprayed on articles to protect them against corrosion. As it is possible to spray either nickel or monel metal, these highly resistant metals can be used advantageously as a protection against corrosion.

On account of the coating being more or less porous, electropositive metals such as zinc are better to use to protect metal under mild corrosive conditions. It is said that the zinc oxide and carbonates which form throughout the zinc coatings are very tough and adherent and finally bring the corrosive action to a minimum.

During the war this spraying process was used extensively for coating shells with zinc, copper or lead in order to correct imperfect dimensions, weight or balance.

Calorizing as a Protection for Meals to Resist Heat.

In developing the process of calorizing or coating metals to resist heat, it was noticed that a cut surface of aluminum showed a bright lustrous surface which became dull after a short time due to oxidization. It was also found after longer exposure that little change takes place in the strongly adherent coating of oxidization.

When aluminum is alloyed in solid solution with other metals, it still retains this property and serves as a protection. It is this property that has been taken advantage of in the process of calorizing. In other words, calorizing consists of the formation of a surface alloy of aluminum on either ferrous or other metals. There are now two methods of calorizing; one known as the powder process and the other, the dip process.

Powder Process.

In the powder process the parts to be treated are placed in an air-tight receptacle partly filled with the calorizing mixture which consists of finely divided metallic aluminum suspended in aluminum oxide. Hydrogen gas is admitted into this container and it washes out all the air and provides a reducing atmosphere. When heated to a high temperature the particles of aluminum, which are kept separate by the alumina, make contact with the material being treated, infusing into the exposed surfaces. The depth to which the aluminum penetrates is governed by varying the length of the treatment and the composition of the mixture. When parts thus treated are subjected to high temperatures in air, a thin but impervious coating of oxide forms, which protects them from deterioration by scaling.

Dip Process.

What is known as the dip method was developed by C. Dantsizen, of the Schenectady Research Laboratory. It consists of properly fluxing the parts, which are then immersed in a molten bath of aluminum. This method has the advantage of being very rapid and is well adapted to the treatment of small parts in large quantities which do not warrant much added expense. Although the dip method gives a lighter coating than is obtained with the powder method, it gives a thoroughly reliable coating of aluminum alloy and is particularly well adapted to parts of small cross section. Where the usage is not very severe, parts of greater thickness may be adequately protected by this process. Some of the products already successfully treated in his way are iron wire, heating units, grids, stove burners, lighting fixture parts, gas engine exhaust mufflers, oil burner shields, miscellaneous stampings, etc.

Calorizing should not be confused with sherardizing or galvanizing, as each method for protecting metal is different. Zinc would have no value whatever as a metal for resisting heat. Zinc is used chiefly for resisting corrosion where water and air predominate while calorizing is used to protect metal against the ravages of heat.

Calorizing is simply a dense coating which cannot be readily scraped off, and it will stand a considerable amount of abrasion.

Fig. 1 shows a section of calorized metal after steel is calorized, a coating is formed which consists of a thin alloy layer very rich in aluminum. As the calorized article is subjected to heat, the alloy penetrates deeper. Should the layer of oxide become damaged, the specimen will renew its coating when again subjected to oxidizing conditions.

The life of calorized material is chiefly dependent upon the proportion of the cross section affected by the alloying and the percentage of the aluminum content. For example, if two steel rods, one having half the diameter of the other, were treated to the same depth, the smaller specimen would be affected to a greater depth than the larger. It is, therefore, obvious that the smaller piece of steel would have a greater resistance to prolonged heat.

Tests have been made on calorized sheet metal used for oven linings for ranges, and it has been found that commercially pure iron took a more perfect calorized coating than steel. This is due to the commercially pure iron being practically free from gas, while steel is continually giving off gas at high temperatures which cause pinholes in the coating or blisters in the metal. It is extremely rare to encounter blisters in calorized commercially pure iron.

It has also been found that carbon in steel increases brittleness and that manganese and silicon both tend to decrease resistance to oxidization, all of which emphasize the importance of using a pure base metal. Calorizing has been recommended for oil tube stills, condensor tubes, valves, piston heads, and a substitute of clay parts in connection with hot molten glass. It is likewise used for pipe for conveying molten glass.

In the enameling industry it is used for furnace parts to support material to be enameled. Calorizing has also been recommended for pyrometer protection tubes, and increased life of the couple has been obtained by calorizing.

(To be continued)

The Transportation of Tungsten Ore

STARTING May 26 from Weehawken, N. J., the most valuable train of ore ever carried by any railroad was hauled to Niagara Falls, N. Y., over the River Division of the New York Central Railroad. It was consigned to the Electro Metallurgical Company for the account of the Crucible Steel Company of America.

The ore was tungsten, valued at $512,910. This costly and indispensable element in the manufacture of high speed tool steel and other forms of modern necessity, such as filaments for electric incandescent globes, telephone magnets and the like, came from the other side of the world and involved the labor of hundreds of men in bringing it to its destination.

It came from China, far in the interior, 1,100 miles from Shanghai, from which port it was shipped to America. It took the coolies six weeks to bring it down the river from the mines in the Shi Wai Sham district, 600 miles north of Canton, to Kiukiang and thence for 500 miles more down the Yangtsi River to Shanghai, from which port it still had 10,000 miles more to cover before reaching America.

Tungsten is in many respects unique. In the first place, it is the heaviest of all the metallic elements, being two and one-half times as heavy as iron, while its melting point is 5,915 deg. F., far higher than any other known metal. In fact, it is seldom or never wholly melted in commercial steel melting furnaces, but enters the molten steel in solution, much as sugar dissolves in hot coffee or tea. Mixed with steel, it enters into the manufacture of high speed cutting tools such as are used in rifling guns of the army and navy and for the guns themselves in certain instances, also in the making of certain kinds of saws, punches and dies.

Were it not for tungsten's part in the making of tool steel it would not be possible to make the modern automobile for anything near the price for which it is produced, for it has revolutionized machine shop practice and production methods. This is its greatest use, followed closely by its value in making the filaments for incandescent electric lamps. It is susceptible of being drawn into very fine wire, as small as four ten-thousandths of an inch in diameter, which is about one-quarter the diameter of a human hair.

High speed tool steel is an American invention, dating to the beginning of the present century, and the high speed tool steels of this company are the standard of the world. In their manufacture from 12 to 20 per cent of tungsten is used in the steel, while in

Most valuable ore shipment ever handled by railroad. (Left insert)—Carrying ore overland from mine to river. (Right insert)—Transferring ore from small to large boats on the Yangtsi River.

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the drawing of the electric light filament the pure tungsten is employed unalloyed. It is so hard that it will readily scratch quartz.

W. F. Carman, vice president of the China Commercial Company of New York, has had some dramatic experiences in the country from which we draw our main supply of tungsten. Robbers, kidnappers, revolutionists and shallow rivers make up a few of the trials through which the tungsten miner and transporter is forced to make his way with his valuable cargo. Last year, while traveling out with a cargo of ore from the mines, his party of 50 boats had tied up in the middle of the river when they were boarded during the night by robbers. Guards saw them, however, and subdued them before they could do harm. Recognizing the power of the robbers of interior China, the company operating the mines employs a man for the sole purpose of subsidizing the bandits as well as the government that happens to be in power at the moment, else they would never get their material from the interior to the rivers for transport to the seacoast.

These deposits of tungsten in China have been known only for ten years, although the Chinese have used gold coins for 3,000 years and many other rare metals for centuries. The mines in that country now produce more of the metal than any other section of the world. The first deposits were discovered in the southwestern part of Kiangsi by a German priest, but it was Chan Ku Lee, of the Kong Ku On Mining Company, who was first to locate deposits in northern Kwong, from which large quantities are shipped. Metallic tungsten is obtained through the reduction of ores and is a gray, granular mass, but if wrought, looks like iron or steel and can be polished. Like zinc, its structure is changed by working but, unlike that metal, it develops great tensile strength and can be drawn into a filament so fine that one pound of it will be nearly a mile and one-half long, just enough to make 25,000 electric lamps of 25 Watt size.

The almost incessant internecine trouble in the south of China has had a serious effect on the mining of tungsten and property after property has been abandoned, the main source of supply for the last two years having been the Shi Wai Sham district, which lies about 600 miles north of Canton. At first shipments were brought down over the mountains direct to Canton, but the growing disorders in the south caused the abandonment of this route. In one instance the company was forced to pay $50,000 ransom to bandits for the release of five of its men. Shipments were later brought out by way of Nan Chang, Kiukiang and down the Yangsti river to Shanghai. In America this distance would be covered in about 24 hours. There it takes six weeks.

Interruption to transportation, is one of the most serious obstacles with which the Chinese miner has to contend. When the ore leaves the mine it is carried some 15 miles down the mountain to the concentrating sheds, where it is crushed, after which it is dried, sampled and bagged for its 10,000 mile journey to the markets of the world.

Coolies with shoulder poles carry the ore in two bags of 100-pounds each from the concentrating plant to the river, where it is loaded on sampans. These little boats, because of the shallow river, can carry but one ton each and many times on its long journey to Shanghai it is transferred to larger and still larger boats. At the beginning even the small boats have to be often poled off sandbars in the stream.

Misleading Results Possible in Microscopic Examination*

Recognition of the fact that many steel failures may be traced to non-metallic inclusions in the steel has led users to examine their steels carefully under the microscope before putting them into service. This examination is intended to disclose whether the steel is of sufficient cleanliness to give satisfactory service. Precautions of this sort are the part of wisdom, precluding as they do the possibility of loss after expensive working operations have been put upon the material. The warning we wish to issue here, however, is that unless the microscopic examination is carried out with extreme care, very misleading results may be obtained, and perfectly sound steel rejected as unsuitable.

While non-metallic inclusions are undesirable in steel when present in excessive amount, it is impossible, in commercial practice, to make steel altogether free from any inclusions whatever. The aim of the steel-maker is to make steel in such a way that impurities are not only held to the absolute minimum, but finely divided and well distributed in the steel.

Where, through improper handling in the steel-making processes, these inclusions segregate, the steel is faulty and should not be used. In rolled bars, these segregations take the form of strings, which may vary in length from 1/8 of an inch to several inches. They generally consist of the slag-forming materials encountered in steel works practice, namely manganese sulphide, manganese silicate, iron silicate and combinations of these.

These segregations of non-metallic matter are easily discernible under the microscope and are justification for rejection of the steel, since these inclusions are generally brittle at ordinary temperatures, and in members subjected to repeated stress or to alternating stress, constitute areas of weakness. When there are repeated bendings a small crack is liable to begin at one of these inclusions and spread gradually into the remaider of the steel, leading to so-called fatigue failures.

The methods used in preparing a specimen of steel for examination are of utmost importance if misleading results are to be avoided. Usually a piece is given a series of fine grinding operations, using finer and finer wheels and papers until a very smooth surface has been secured. The steel is then given a final buffing, which leaves it with a mirror surface.

But herein lies the danger of misleading results. Unless the grinding and polishing operations are carried out by an experienced operator, there are likely to be small pits, due to smearing instead of abrasion, or due to excessive pressure in some of the early stages of grinding. Incomplete polishing and tears, called "comet tails," are common results of improper preparation, and are liable to mis-interpretation.

A criterion of good polishing is the appearance of non-metallics clearly outlined with a narrow black rim, and the complete absence of any black spots having no actual material in them, which might be interpreted as non-metallic inclusions.

It is generally possible for a thoroughly experienced observer to determine the nature of an inclusion from its color and its shape. Improper preparation of the specimen, however, may give the cleanest steel a very unfavorable appearance under the microscope.

*Reprinted from U-loy News.

Reactions in the Iron Blast Furnace*

The study described in this paper, on the reactions in an iron blast furnace, is part of the investigation being conducted by the Bureau of Mines on combustion of coke and reduction of iron oxides in the blast furnace. Previous study of the combustion zone of the iron blast furnace, by means of a series of gas samples taken through the tuyeres across the hearths of 13 blast furnaces, showed that the combustion of the coke in the blast furnace hearth is complete at a distance of 32 to 40 inches from the nose of the tuyere, measured horizontally toward the center of the furnace. The results of this previous work showed that practically all of the oxygen disappears at a distance of approximately 30 inches from the nose of the tuyere.

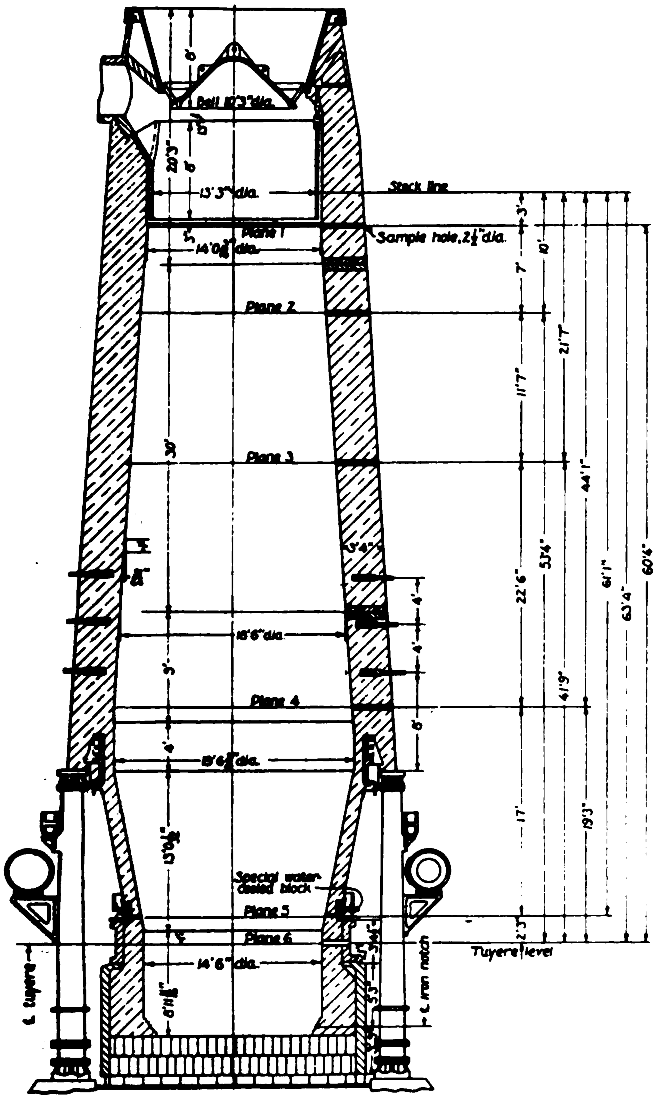

FIG. 1—Section of 300-ton blast furnace showing position of gas-sample holes.

In order to determine the height at which oxygen is found in a vertical direction above the tuyeres (it had been suggested that the combustion zone turned upward near the tuyere) and to obtain comparisons with the samples taken at the Bureau of Mines experimental 5-ton blast furnace at Minneapolis, the bureau extended the gas sampling on a commercial furnace to a number of planes between the tuyere level and the stock line. The sampling was conducted on a 300-ton furnace, making foundry iron, operated by the Central Iron & Coal Company, at Holt, Ala., by S. P. Kinney, one of the authors. The furnace was smelting southern red and brown ores and nodules from pyrite sinter. Fig. 1 is a vertical section of the furnace showing the six planes sampled.

The method of sampling the gases was similar to that described by Perrott and Kinney. A water-cooled tube was used, and the samples were collected over mercury and analyzed in a modified (Burrell) type of Orsat apparatus. Samples were collected in each plane at intervals of approximately 4 inches between the inwall and the center of the furnace. The planes were repeatedly sampled on each day of sampling and on several different days. The results of this work are briefly presented here; a more complete report is being published as Technical Paper 391 of the Bureau of Mines.

This investigation of a 300-ton furnace in operation proves the following:

1—The oxygen of the blast has been consumed, in the process of combustion, at a point 27 inches above the center line of the tuyeres, and the penetration of the combustion zone in a vertical direction is equivalent to that in a horizonal direction at the tuyere level.

2—The composition of the gas across a plane 20 feet above the tuyere level is constant. The excess oxygen therein is due to reduction taking place in the bosh.

3—As the composition of the gas at plane 4 is constant, the abnormal gas composition shown in the center of the hearth near the tuyere level is a local condition. This is due to a combination of three factors, these being, in order of importance: (a) restricted circulation of gases in the center of the hearth area; (b) so-called direct reduction, and (c) formation of cyanides. (The Bureau of Mines has Technical Paper 390 on cyanides in the press.)

4—The uniformity of gas composition at plane 4, which is 20 feet above tuyere level, does not indicate uniformity of flow.

5—Analyses of samples at planes 3, 2, and 1, which were approximately 41, 53, and 63 feet above the tuyere level, show unequal gas composition across the planes. It is pointed out that this is due to the effect of four factors: (a) a difference in porosity in the stock column; (b) segregation of iron oxides in the outer part of the column; (c) unequal stock flow; and (d) unequal gas flow.

6—The results indicate that better practice with lower coke consumption might be obtained if operation could be so maintained that the gas composition on any plane above No. 4 would be uniform in CO_2 content, and also so maintained that the CO_2 content of the gases would increase with the distance from the hearth level. This condition will exist if the materials are so arranged in the stack that the composition of the charge is uniform throughout the column. It then follows that the flow of gas and stock in the column must be maintained uniformly.

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*Excerpt from Bureau of Mines Reports of Investigations, Serial No. 2747, April, 1926.

NEW EQUIPMENT SECTION

Mayers Vertical Sand Damper

The Mayers Vertical Sand Damper manufactured exclusively by H. L. Dixon Company, Pittsburgh, Pa., is designed to meet the demand for a valve suitable for use on horizontal hot gas ducts. Operated by one man, it cuts off gas as soon as the damper is in place and the space between the two valve plates filled with sand which also closes any small leaks. After the joints between the plates and seats have become tarred to insure tightness, sand may be removed to allow ventilation between the two plates for cooling purposes.

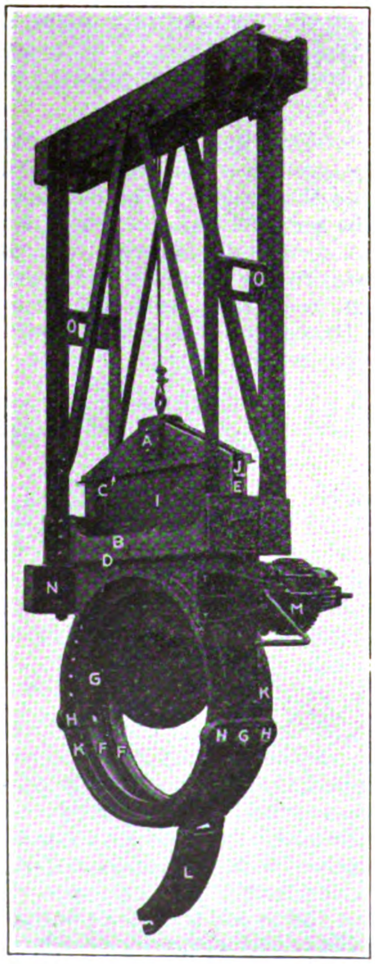
In general it consists of a cast iron body open at the top where it is slightly enlarged, and a double-seated internal chamber for receiving the two discs or plates, similar in this respect to ordinary double disc gate valves. The two plates are connected only by a U-shaped bar at their upper ends, sufficient resilience being provided to permit the plates to spring towards each other slightly in order to break the adhesion by tar deposits.

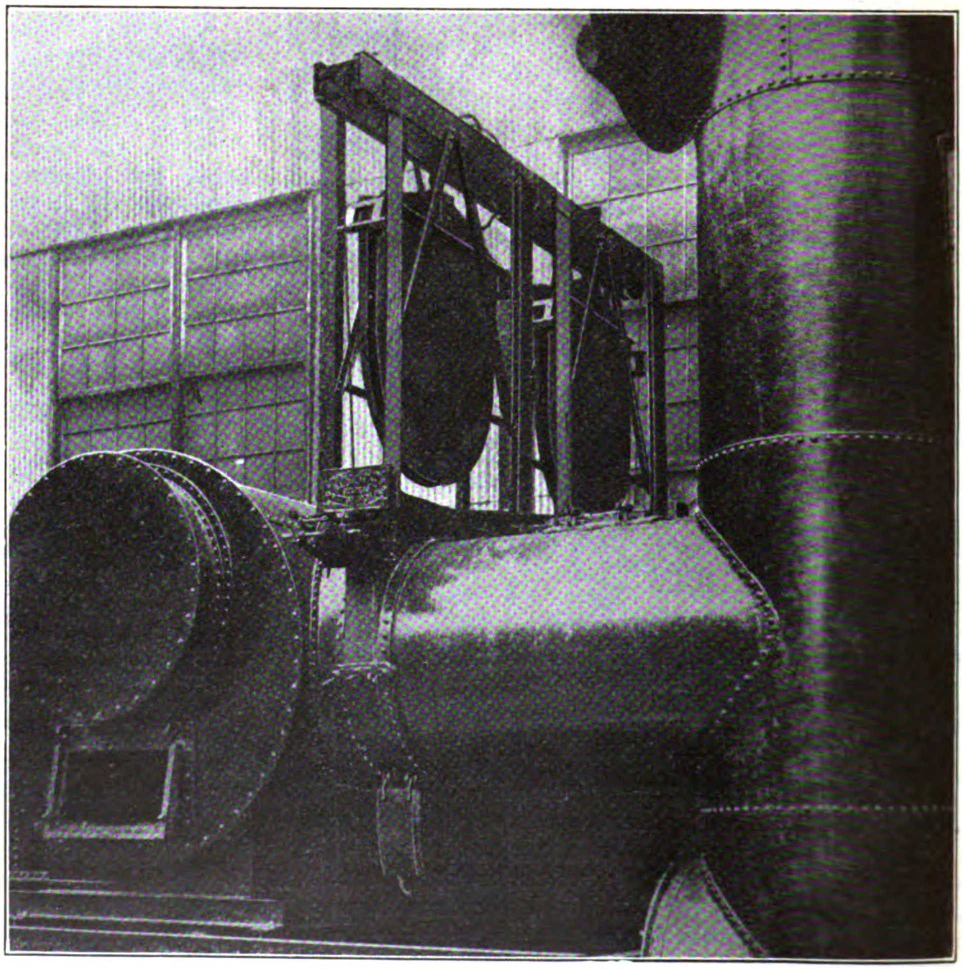
When the valve is closed the space between the plates is filled with sand. The enlarged opening at the top of the valve body is also filled level full of sand which surrounds the plates at this point forming an effective seal against the escape of gas to the air. The internal seal does not depend upon the close seating of the plates but the effective seal consists of the sand diaphragm between the plates which serve as container for the loose sand.

In cases where one of the plates only is in contact with the hot gas, it is furnished in cast iron, the other plate being ¼ inch to ⅜ inch steel plate. When both plates are required to resist the effect of hot gas both are furnished in cast iron.

Poke holes are provided for loosening sand so that it will fall through the sand door to permit tapping plates or prying them loose in case they may become tarred tight. For mounting on existing gas mains, the body is cast in two halves. It is then only necessary to cut out a section of pipe and silp damper over pipe collar-fashion.

It is claimed that in the old type horizontal sand dampers there is always difficulty in their operation. If this type has been closed for long intervals, it is often impossible to move them without injuring the main in which they are installed. On the other hand the new vertical type can be operated very easily at all times and under all conditions, and by one man.





(Left)—Showing construction of Mayers vertical sand damper. (Right)—Installation of Mayers vertical sand dampers on a gas producer line.

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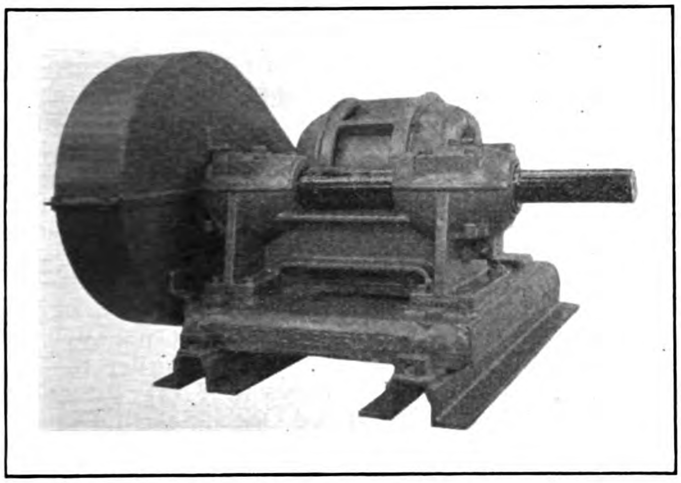
Back Gearing for G. E. Motors

A back geared attachment designed to operate under the most unfavorable conditions, is announced by the General Electric Company for use with its "500 series" induction motor. This attachment is of unusually strong construction, is easily installed and easily adjusted.

The base, to which the motor and back shaft pedestals are bolted and doweled, is a single, large casting. A special unit-type pedestal is used, one casting forming the housings for the large back shaft bearings. Thus maximum rigidity and permanent, correct alignment of shafts, and meshing of gear and pinion, are assured.



Back-geared induction motor.

The back shaft is provided with shoulders to limit end play and is made of special steel. It is supported by two extra large, double-seated, split bearings in dust-proof housings, holding oil sufficient for a number of months' operation.

A split gear case, fabricated from steel plates, protects the gear and pinion from dust and retains the grease or oil in which the gear runs. Two standard gear ratios are available. Steel or fabroil pinions with cast iron gears may be used. Two box type welded rails with an easy adjusting feature complete the equipment.

New Elevating Platform Truck

The Yale & Towne Manufacturing Company of Stamford, Conn., has recently brought out a new elevating platform truck which is designated as Yale K23E.

This truck is designed primarily to carry the unusually heavy loads that are found in many industries. Although this machine is not of the high lift type, such as the K22, it does embody the desirable self-loading feature. It has so many intra-plant applications that a simple arrangement of the movement of materials will keep it working constantly. The time taken to pick up or drop a skid with this truck, as compared with the time required to load other types of trucks, is very small and as a result it is capable of much greater tonnage per day.

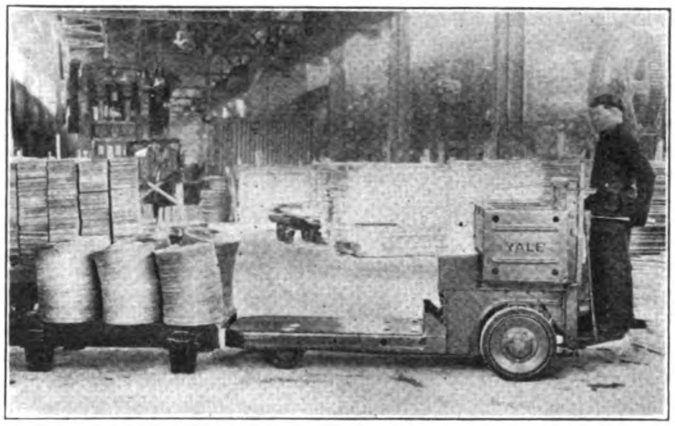
The short turning radius and the narrow width of this machine makes it easy to drive in and out of box cars or narrow aisles. Hardened steel steering pivots with bronze bushings and the high pressure lubricating system reduces friction and makes steering easy, even when carrying a full load. This easy steering may also be attributed to large tires, both front and rear, which will not squelch out under load, and to a proper distribution of load on the tires.

Heavy pressed steel frame members and unusually large elevating links, which support the platform, admit of its carrying its load with an ample factor of safety. The links are wide and heavy, giving secure support to the platform.

The triple spur-gear elevating mechanism consists essentially of the same unit as is used in the K22 truck, making the major replacement parts interchangeable between models. The elevating platform is raised by means of two large eccentrics mounted on the hoist unit shaft, which draw the platform forward and upward on the platform links. Mechanical upper and lower limit stops assure simple and safe operation of the lift mechanism. The quick speed of elevating will save considerable time during a day's run.

One of the notable achievements of the "K" series of trucks is the spur-gear unit power axle—a sub-assembly, interchangeable with that used in all of the models. Totally enclosed alloy steel gears, mounted on ball bearings and running in oil, insure long life. The universal joints of the unit are enclosed in leather boots packed with grease, completely protecting them from dirt and water. Accessibility and simplicity of construction decrease overhaul and maintenance expense.

The control of this truck—"simple, positive and direct in connecting the operator with the operating part"—follows the Yale standards of safety and is another sub-assembly interchangeable with that of all other K-trucks. The controller used is of the same design used on all Yale Industrial Trucks. It is durable and highly efficient under the most severe working conditions.



Yale & Towne elevating platform truck.

The majority of parts, units and sub-assemblies of the K23E Elevating Platform Truck are standard and interchangable with those of all other models in the K-series. When two or more different K-series trucks are used in one plant, this interchangeability offers definite operating advantages and economies. Because of this interchangeability, considerable economy in truck manufacture is effected, thus establishing new standards of value in industrial truck transportation.

Book Review

Corrosion—Causes and Prevention. By Frank N. Speller, Director of Metallurgical Department, National Tube Company. 621 pages, 6x9, buckram binding, 125 illustrations. Price postpaid, $6.00. This book is an authoritative presentation of the available information on the corrosion problem from the standpoint of the engineer. It combines in one volume a thorough treatment of the theory of corrosion and a detailed description of methods of preventing corrosion. It deals particularly with the ferrous metals. The first part describes the facts and factors already known, together with the generally accepted Electrochemical Theory of Corrosion, leading up to a system of classification of corrosion phenomena and the principles of corrosion testing.

The second part discusses the practical application of the facts and principles already established with reference to corrosion prevention under the conditions found in the air, underwater, underground, in closed water systems, steam boilers, in the chemical industries and in other situations. This involves a choice of using a more durable metal or a suitable protective coating, or in certain cases, conditioning the water.

Contents—Introductory Outline of the Corrosion Problem. Nature and Mechanism of Corrosion—Theories of Corrosion. Influence of Methods of Manufacture and Treatment. Influence of Factors Internal to the Metal—Composition. Influence of Factors External to the Metal—Classification of Corrosion: Principles and Methods of Corrosion Testing. Relative Corrosion of Ferrous Metals. Prevention of Corrosion in the Atmosphere. Prevention of Corrosion Underwater. Prevention of Corrosion in Closed Water Systems by Removal of Dissolved Gases. Prevention of Corrosion in High Pressure Steam Plants—Boiler Water Treatment. Prevention of Corrosion in Steam and Hot Water Heating Systems. Chemical Corrosion. Prevention of Corrosion Underground. Stray-current Electrolysis.

Leland Russell van Wert, for the past six years a member of the faculty of the Harvard Engineering School, has been named assistant professor in metallurgy at the Carnegie Institute of Technology for next year, according to an announcement from President Thomas S. Baker. The appointment is announced as a further step in the re-organization of the Department of Mining and Metallurgical Engineering, Professor James Aston, former metallurgical engineer with the A. M. Byers Company, having been placed in charge of the department several months ago subsequent to the death of Professor Fred Crabtree and the recent resignation of Professor F. F. McIntosh.

The recent re-organization of the personnel of the Department of Mining and Metallurgical Engineering at Carnegie, it is announced, will in no way affect the present status of the newly-organized Bureau of Metallurgical Research. The Bureau, under the direction of Dr. Francis W. Walters, Jr., and Dr. V. N. Krivobok will continue to conduct research studies in physics as applied to metallurgy and metallography, while the Department of Mining and Metallurgical Engineering will be concerned, as in the past, with instructional work for students and research in mining and metallurgy in co-operation with the U. S. Bureau of Mines.

PERSONALS

Johann Hahn formerly with the Lewis Foundry & Machine Company, Pittsburgh, Pa., is now with the Wellman-Seaver-Morgan Company, Cleveland, Ohio.

* * *

H. E. Gilmore became manager of the St. Louis Branch of The Timken Roller Bearing Service & Sales Company, effective May 22. Mr. Gilmore's promotion follows several years sales experience with this company under the direction of Frank J. Kemper, manager and district supervisor of the Chicago branch.

* * *

A. G. Ripberger, until recently assistant general superintendent of operations, has been appointed chief engineer of the United Alloy Steel Corporation, covering all divisions. He will be in charge of all phases of engineering and of the operation and maintenance of all power, steam and gas plants.

* * *

Wm. P. Chandler, Jr. has resigned his position as special engineer for the Carnegie Steel Company, his resignation to take effect on July 1, in order to join the organization of the American Heat Economy Bureau, Inc., in charge of the Open Hearth Department.

Mr. Chandler received his engineering training at Cornell University and entered the steel business in 1910 at the Clairton plant of the Carnegie Steel Company. In 1917 he resigned the position of steam engineer for this company to take care of the combustion problems of the Cleveland Furnace Company. In 1918 he became assistant fuel and experimental engineer of the Duquesne Works of the Carnegie Steel Company and was appointed engineer for this plant in 1922. During 1924 he was appointed special engineer for the Carnegie Steel Company in charge of fuel and combustion problems.

* * *

K. Huessener, president of the American Heat Economy Bureau, Inc., 926-930 Wabash Building, Pittsburgh, Pa., sailed for Europe on June 15. Apart from taking care of his British interests, Mr. Huessener intends to make an extensive study of open hearth design in the various European countries. Mr. Huessener will be absent for about three months.

COMING MEETINGS

September 20-24 — American Society for Steel Treating. Annual Convention and National Steel and Machine Tool Exposition at Municipal Pier, Chicago, Ill. W. H. Eisenman, 4600 Prospect Avenue, Cleveland, Ohio, secretary.

* * *

Sept. 27-Oct. 1—American Foundrymen's Association. Second international foundrymen's congress, Detroit. R. E. Kennedy, secretary, 909 W. California Street, Urbana, Ill.

TRADE NOTES

Effective June 1, Mr. Lawrence K. Diffenderfer tendered his resignation as secretary and treasurer of the Vanadium Corporation of America. Mr. Diffenderfer is leaving Vanadium Corporation of America to engage in special accounting, tax work, industrial plant and mine valuation, and work of that nature. He is to be succeeded by Mr. Edgar R. Alpaugh. Mr. P. J. Gibbons, at present chief clerk of the Bridgeville plant of the Vanadium Corporation of America, has been elected assistant treasurer. Mr. J. A. Miller, Jr., at present general sales engineer will become assistant general manager of sales with headquarters in New York. Mr. H. T. Chandler, assistant to the president, who is now located in Detroit, will be transferred to the New York Office, in the same capacity. Mr. C. N. Dawe, at present with the Studebaker Corporation of America, at Detroit, will become affiliated with the Vanadium Corporation of America as manager of the Automotive division, with headquarters in Detroit. Mr. T. N. Bourke, at present district sales manager Division with headquarters in Detroit.

* * *

The U. G. I. Contracting Company wishing to facilitate and expedite the work of its sales department relating to Industrial Gas Engineering has closed its office at Pittsburgh, Pa. Mr. A. E. Blake heretofore in charge, will continue his work at the main office at Broad and Arch Streets, Philadelphia, Pa., as sales engineer.

* * *

Gibb Welding Machines Company, Bay City, Mich., manufacturers of eletric arc, spot, and seam welders, broke ground June 10 for an addition to their factory that will more than double their present floor space.

* * *

The Colorado Fuel & Iron Company, Minnequa Works, Pueblo, Colo., who recently put into operation two Wellman-Seaver-Morgan Company's Type L No. 10 Mechanically Operated Gas Producers, have placed a further order for 16 additional producers duplicates of the first two.

* * *

The Standard Asbestos & Cork Company, of 541 South Troost Street, Tulsa, Okla., has been appointed distributor for Botfield Refractories Company, Philadelphia, Pa.

* * *

The R. H. Beaumont Company, specializing exclusively in coal and ash handling equipment for boiler and gas houses, announces the opening of a western branch at 1544 Strauss Building, 310 South Michigan Avenue, Chicago. H. E. Birch, for many years sales manager at Philadelphia, will be in charge. Preliminary designs and estimates, as well as contract work and construction in the Middle West, will be handled from this branch.

* * *

The Bailey Meter Company, Cleveland, Ohio, has transferred their Pittsburgh Branch Office to 1815 Oliver Building, where they will have larger quarters and be able to render better service. This office will be in charge of Mr. W. R. Little, who has recently returned from an extended business trip in the interest of this company in Europe.

* * *

The Omaha Branch Office of the Timken Roller Bearing Service & Sales Company, formerly located at 2524 Farnum Street, now occupy larger quarters at 2240 Douglas Street. Complete service stocks for authorized distributors will be maintained as in the past. The management will continue under the direction of A. D. Hackim.

* * *

The Alloy Cast Steel Company, Marion, Ohio, has recently been organized by John D. Owens, C. A. Owens, M. C. McNeil, H. J. Barnhart, Frank D. Glosser, Walter A. Dorsey, and E. J. Schoenlaub, all of Marion, Ohio. The company has purchased the electric steel foundry of the Fairbanks Steam Shovel Company, which was recently sold at receivers sale. The plant is now being completely overhauled and enlarged to a capacity of 400 tons of steel castings per month. Extensive addition of modern foundry equipment will be installed at once. The new company will manufacture high grade electric steel castings in carbon, manganese and other alloy steels.

TRADE PUBLICATIONS

Recuperators—The Mantle Patent Unit Recuperator is the title of an eight page bulletin issued by the Mantle Engineering Company, Oliver Building, Pittsburgh, Pa., describing the principle, construction and advantages of their unit recuperator.

* * *

Water Softener—Graver Zeolite Water Softener is the title of bulletin No. 509 just published by the Graver Corporation, East Chicago, Ind. The bulletin is very completely illustrated both with views of installations and of the softener and equipment. The softener uses the downflow method of softening with a natural zeolite mineral supported by a strainer plate. This strainer plate, which is attached to the shell of the softener, is perforated with equally spaced slots to provide thorough distribution necessity of a concrete fill in the bottom of the softener tank.

* * *

Steam Economy—The Republic Flow Meters Company, 2240 Diversey Parkway, Chicago, Ill., has just issued a bulletin on steam economy. This bulletin is considerably more than a catalogue, being a compilation of the experience of the company's entire engineering force covering a period of five or ten years on the subject of methods for reducing steam costs.

* * *

Chains—S. G. Taylor Chain Company, 140 South Dearborn Street, Chicago, Ill., have issued a revised general catalog which contains complete data to safe loads on Double Sling Chains when used at various angles.

* * *

Chain Drives—Machine Tool Drives is the title of a 36-page book issued by the Link-Belt Company of Chicago, Indianapolis, and Philadelphia. A number of subjects of interest to the machine tool manufacturer, such as speed reduction, unrestricted center distances, working contact of teeth, and the application of Silent Chain Drives to tool maintenance costs, are discussed and delineated upon at length.

Machine Shop Directory

We have added to our list of Directories the 1926 issue of Machine Shops of the country. This lists almost 12,000 machine shops in the United States.

The Directory is divided into states, and the states into cities or towns, and the names of companies are printed alphabetically, forming a rational index.

It is interesting to note that Ohio leads with the number of Machine Shops, followed by Illinois, New York and Pennsylvania. Nevada has the smallest number.

Like the Iron and Steel Plant Directory, which we have been publishing for a number of years past, we have included the personnel of the executive and operating officials, where available; also products, capitalization and railroad connection.

The Machine Shop Directory will be mailed to you postpaid, $20.00. Only a limited number are printed.

The order blank below is for your convenience.

Order No.........

..........................., 1926.

The Andresen Co., Inc.,
Box 65, Pittsburgh, Pa.

Please enter our order for............copies of the 1926 Directory of Machine Shops, for which we agree to pay $20.00 per copy.

Signature ....

Address ....

City ....

JUL 7 1926

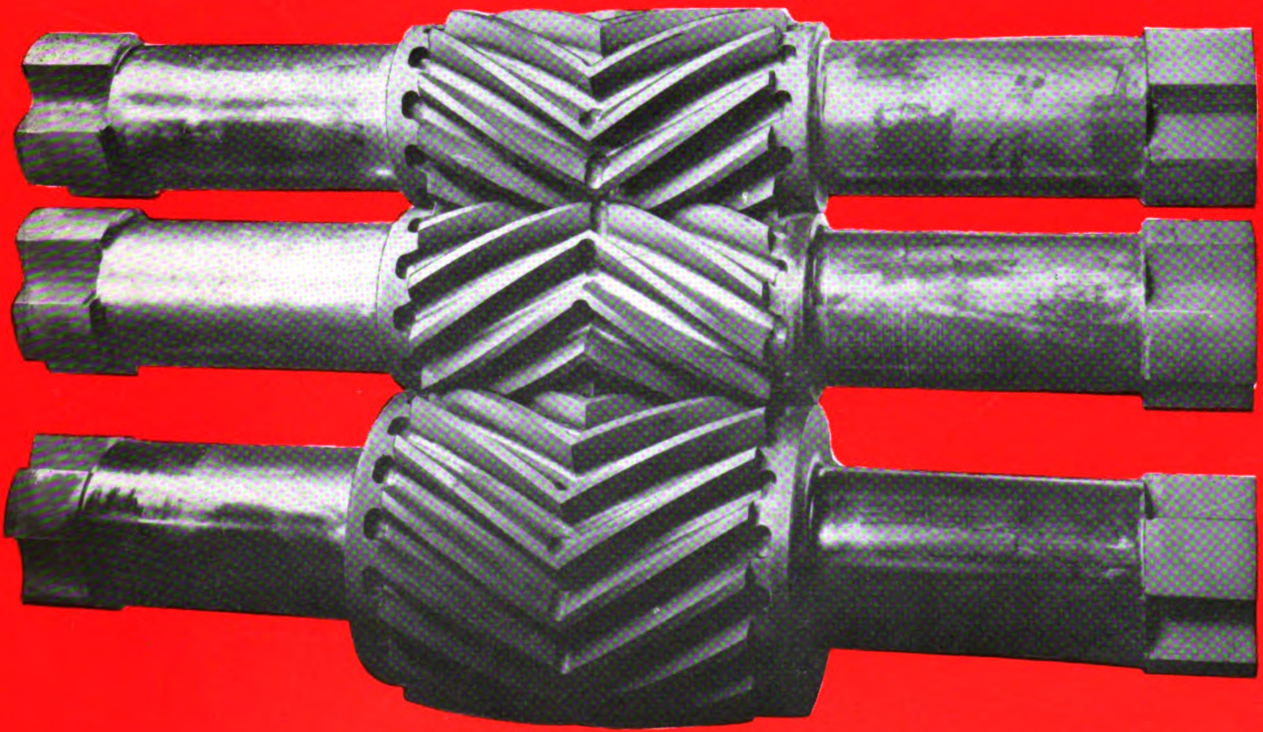
The Blast Furnace and Steel Plant

Member of the Audit Bureau of Circulations

PITTSBURGH, PA., JULY, 1926

Entered as second class mail matter at Pittsburgh, Pa., under the act of Congress, March 3, 1879.

Mo-lyb-den-um
ALLOY PINIONS
FOR 32"X48" PLATE MILL



Wheeling Mold & Foundry Co.
Wheeling, West Virginia